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CONTRACTOR REPORT ARLCD-CR-83033

M577 FUZE PRODUCT IMPROVEMENT PROGRAM: MODIFIED SETTING CLUTCH

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US ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
LARGE CALIBER
WEAPON SYSTEMS LABORATORY
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M577 MTSQ Fuze
Setting Clutch

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The objective of this effort was to reduce the cost of manufacturing the M577 fuze by an estimated $.28 each by replacing the existing system of clutch grip rings and spacers with a one-piece clutch sleeve.

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20. Abstract Cont'd.

The one-piece clutch was to achieve the required slipping torque of 9 to 13 in. lb., by varying the clutch's length of engagement on the setting shaft. Several designs of one-piece clutch sleeves were tested, the most significant of which were: 4 fingers or segments (9 tests); 6 segments (29 tests); C-shape with taper (12 tests); solid cylinder with two drive slots (31 tests).

Modified setting shafts, having square and tapered shoulders and a few shallow tapers, were tested in various combinations with the sleeves. Most of the designs did not have repeatability of slipping torque for a given sleeve engagement. The one promising design, the solid sleeve on a .143 degree tapered shaft, showed excellent repeatability of slipping torque at a given engagement, and it had a good gradient of torque vs. engagement. However, when installed in a fuze and then turned from zero to maximum time, back and forth repeatedly, the slipping torque gradually increased to a value outside the desired range. There was evidence of increased coefficient of friction in the formation of a dark gray deposit of aluminum oxide.

Since none of these one-piece sleeves performed in a completely satisfactory manner, Task 1 was terminated 29 January 1982.

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I. INTRODUCTION

During engineering development and advanced production engineering of the M577 MTSQ Fuze, there were many component configurations and assembly variables that were not optimized because of limitations of time and money. The Product Improvement Program (PIP) is directed toward improving and/or optimizing the design.

In response to ARRADCOM Solicitation No. DAAK10-80-R-012 dated 28 March 1980, Hamilton Technology, Inc. (HTI) tendered its Proposal No. 44-9890-A on 20 May 1980, "Technical Proposal for a Product Improvement Program to Modify the M577 Fuze."

On 16 September 1980, HTI was awarded ARRADCOM Contract No. DAAK10-80-C-0203 for the M577 1980 PIP. There were four tasks assigned under the contract, and this document is a final report describing the engineering effort for Task 1, the Simplified Setting Clutch.

The objective of Task 1 was defined in the Scope of Work in the contract as - "Eliminate the Clutch Grip Rings, Spacers, and Clutch Drive Sleeve and replace with a simplified Clutch Sleeve combination." The M577 Fuze now in production uses a stainless steel Clutch Drive Sleeve (9236520) and a mixture of stainless steel Clutch Grip Rings (9236570) and aluminum Clutch Spacers (9236571) to transmit and limit the timer setting torque between the Setting Key (9236517) and the Setting Shaft (9236592). The torque of 9 to 13 in.-lb., at which the Clutch Grip Rings are required to slip, is obtained by varying the quantities of Grip Rings and Spacers, to a combined total of fifteen, in the assembly. Both the Grip Rings and the Spacers are stamped from sheet or strip stock, and the Clutch Drive Sleeve is manufactured by deep drawing, forming, and slotting a seamless tube. The particular goal of this task was to replace the Clutch Grip Rings, Spacers, and Drive Sleeve by a one-piece Clutch Sleeve that would function both as a driving device for setting time and as a torque-limiting device to prevent damage to the setting mechanism.

It was anticipated that a reduction in manufacturing cost of $.28 per fuze would be realized by achieving this goal.

This Introduction is followed by Section II, Summary; Section III, Conclusions and Recommendations; and Section IV, Testing, which is subdivided into: Test Equipment, Test Procedure, Identification of Sleeve and Shaft Designs, Results of Preliminary Tests, Results of Significant Tests, and Other Types of Tests. Included in these sections is some theoretical commentary on sleeve torque vs. length of sleeve engagement, with test data for comparison. A test log of the significant tests is also provided.

Note also that throughout this report when "torque" is mentioned, it is defined as that at which the clutch slips on the setting shaft, the desired range being 9 to 13 in.-lb.

II. SUMMARY OF ACCOMPLISHMENTS

The objective of Task 1 was to improve the fuze setting clutch by replacing the present arrangement of a combination of grip rings, spacers, and drive sleeve with a one-piece clutch sleeve. There was an anticipated cost saving of $.28 per fuze for achieving the objective. The technical approach to meeting the required clutch slip torque of 9 to 13 in.-lb. with a single sleeve was to vary the length of engagement of the sleeve on the setting shaft, thereby producing more or less slipping torque.

In pursuit of this goal, several configurations of one-piece Clutch Sleeves and modified Setting Shafts were made and tested. However, not one of the designs tested, including that in the proposal, performed as desired, for various reasons.

The table below summarizes the tests with the new designs. A detailed log of these tests can be found in Section IV, Testing.

Sleeve Designs	Identification	Test Numbers	Qty. of Tests Done
6 Segments	H	1-9	9
4 Segments	I	10-24, 30-41, 48, 49	29
C-Shape, Tapered	B	25-29, 42-47, 51	12
Solid, 1 Drive Slot	J	50	1
Solid, 2 Drive Slots	K	52-82	31
			82

The objective of developing a one-piece clutch sleeve has not been met. Development has ceased, and the contractor plans no additional effort.

III. CONCLUSIONS AND RECOMMENDATIONS

Despite the effort made to bring the '80 PIP Task 1 to a fruitful conclusion, not one of the clutch sleeve designs tested, including the proposed design, was truly satisfactory for the reasons described under each design in the discussion.

Consequently, it is recommended that the current slip clutch design be retained. Accordingly, development has been terminated, and no additional effort is planned.

IV. TESTING

A. TEST EQUIPMENT

The tools itemized below were used in testing the performance of the one-piece setting sleeves:

- Small two-piece clamp block to hold setting shaft in vise.
- Dial caliper (inch); used depth rod to measure engagement.
- Special socket wrench to fit sleeves with drive slots.
- M577 Setting Key (9236517) with one or two drive tabs.
- Torque wrench - Snap-On Model TE6FUA, 0 to 75 in.-lb.
- Arbor press and notched plate to back-off sleeve from shaft.

B. TEST PROCEDURE

The sequence below was followed for testing the clutch sleeves to determine and record the torque developed at different engagement distances:

1. Place clutch sleeve on shaft until it just touches shoulder or taper; measure distance from end of shaft to free end of sleeve. Engagement of sleeve on shaft is zero here.

2. Press sleeve some short distance onto shaft, using vise or arbor press.

3. Measure distance as in Step 1; record on data sheet.

4. Clamp shaft in fixture in vise.

5. Using torque wrench and socket or setting key, measure the torque as sleeve just slips on the shaft; record on data sheet.

6. Press sleeve further onto shaft; repeat Step 3.

7. Repeat Step 5.

8. Continue measuring distance and torque until torque reaches 15 to 20 in.-lb.

9. Repeat distance and torque measurements for decreasing engagement as sleeve is withdrawn from shaft using arbor press and notched plate.

10. Calculate engagement (see sample data sheet).

11. Plot torque vs. engagement (see sample plots).

C. IDENTIFICATION OF SLEEVE AND SHAFT DESIGNS

Figures 1 and 2 show the various designs of clutch sleeves that were tested under this contract, and Figures 3 and 4 depict the setting shaft modifications that were used in various combinations with the sleeves. These designs are identified alphabetically in the order in which they were tried. Note that shaft configurations different from the present straight one were tested - in particular, chamfered, shouldered, and tapered shapes. However, each sleeve design was <u>not</u> tested with every shaft.

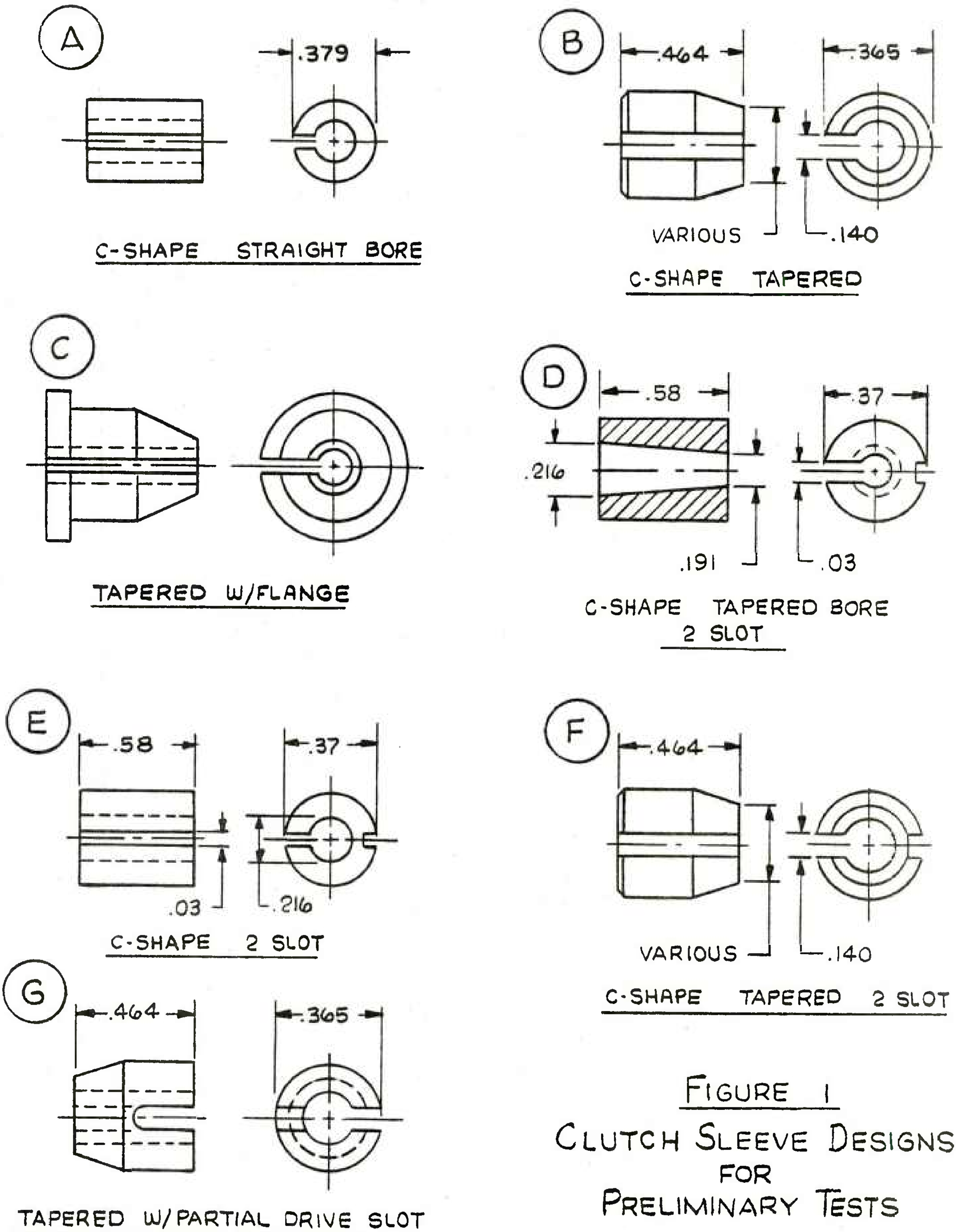


FIGURE 1

CLUTCH SLEEVE DESIGNS FOR PRELIMINARY TESTS

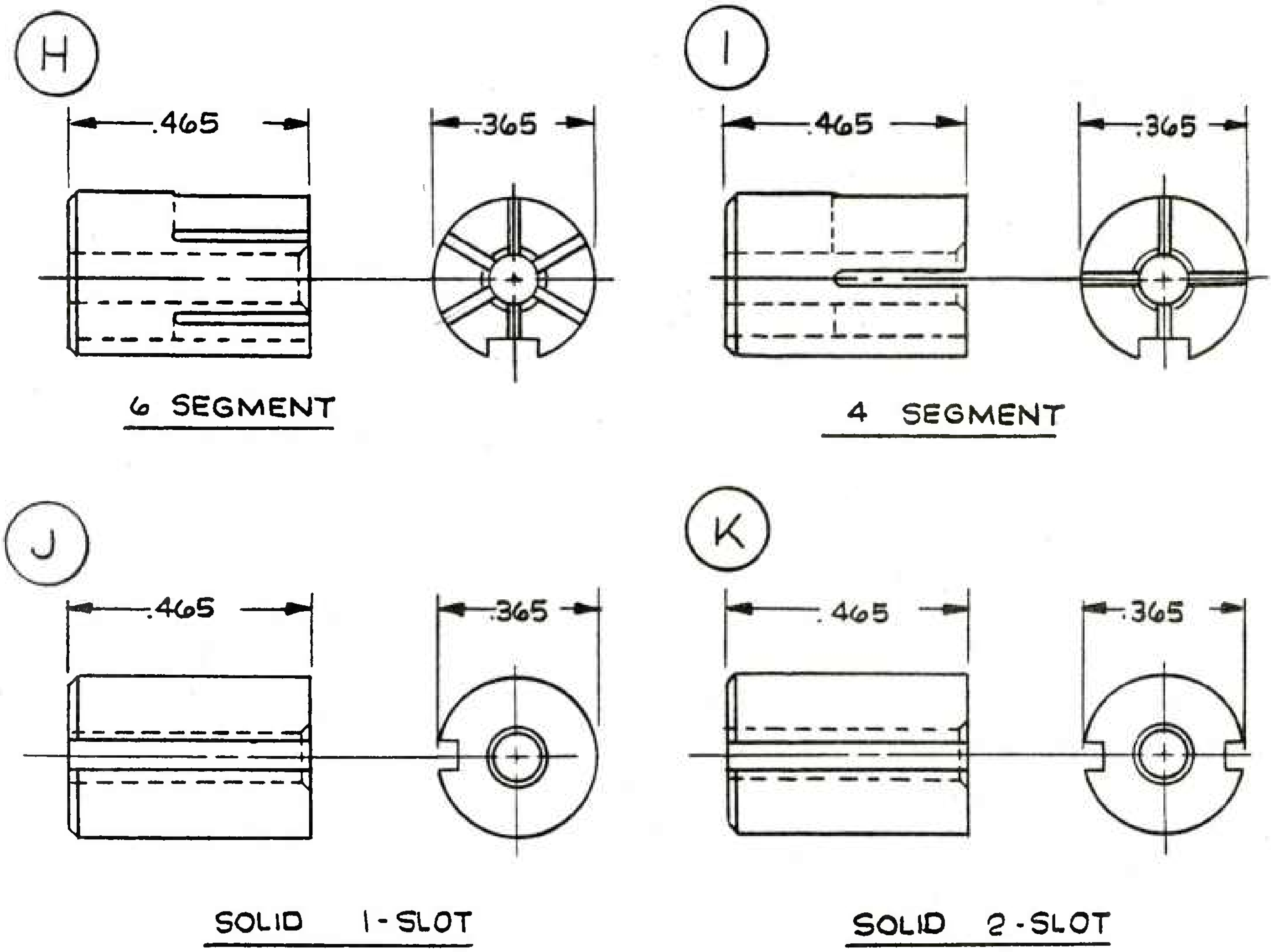


FIGURE 2

SIGNIFICANT CLUTCH SLEEVE DESIGNS

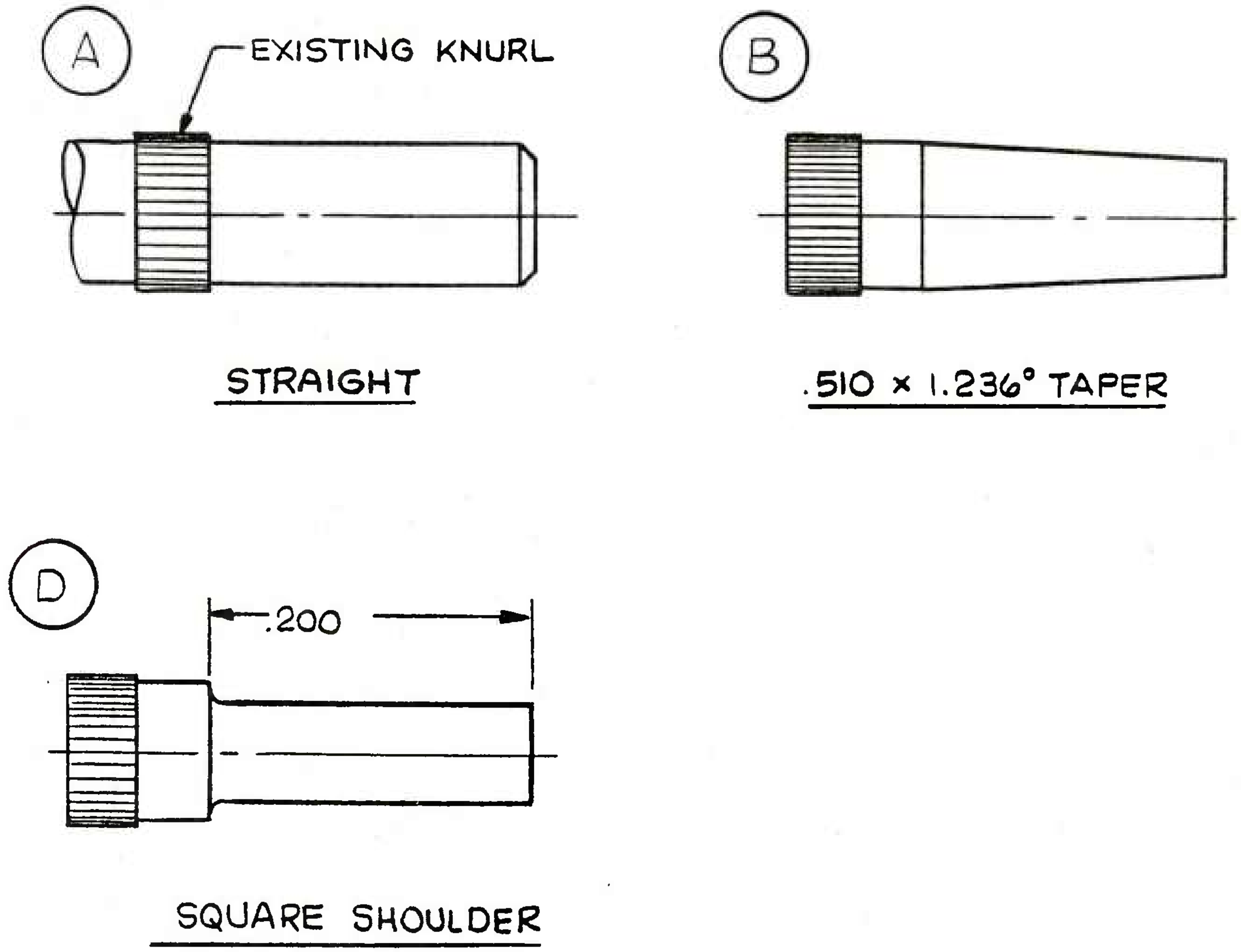


FIGURE 3

SETTING SHAFTS USED FOR
PRELIMINARY CLUTCH SLEEVE TESTS

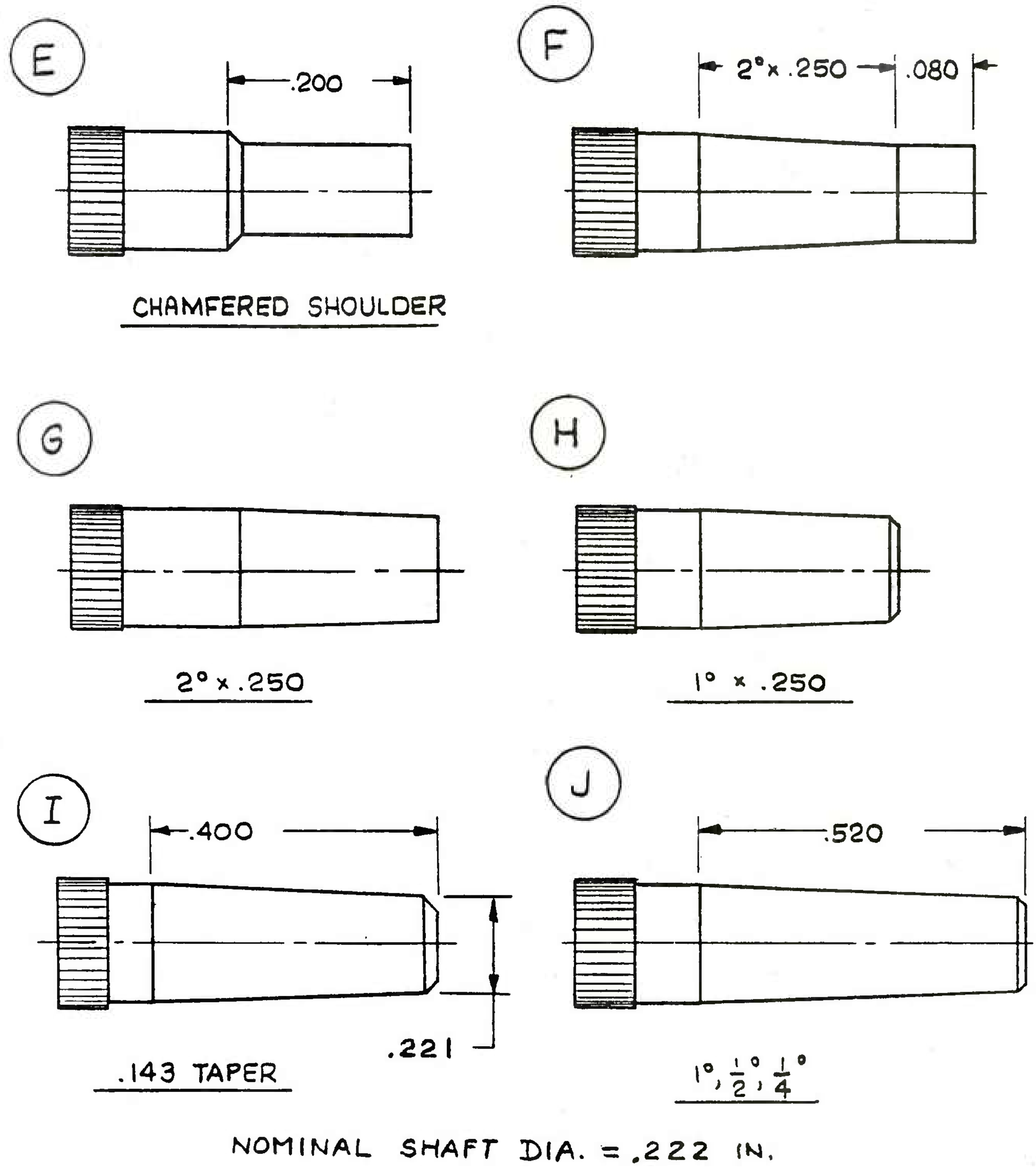


FIGURE 4

SETTING SHAFTS USED WITH SIGNIFICANT CLUTCH SLEEVE DESIGNS

D. RESULTS OF PRELIMINARY TESTS

The sleeve design identified as (A) in Figure 1 is that which was presented as being feasible in the HTI proposal, and it was the first one tested. Design (A) was followed by variations, as shown in (B) through (G) of Figure 1.

Shaft configurations that were tested with those sleeves are shown in Figure 3, (A) through (D).

The fit of the sleeve on the shaft was varied in these tests by using sleeves with inside diameters ranging from .221 in. down to .209 in. Since the nominal shaft diameter is .222 in., the interference fits ranged from .001 in. to .013 in.

Sleeves made of aluminum or stainless steel were tested with shafts <u>also</u> made of aluminum or stainless steel. Some of the steel sleeves were hardened to Rockwell C35 to 38. Also, the lubricant that is used on the present Grip Rings was tried with the result that galling of the shaft was reduced.

For one reason or another, these preliminary designs did not yield acceptable results. For example:

- Al. sleeve on SS shaft - sleeve bore scored by shaft.
- Al. sleeve on SS <u>or</u> Al. shaft - sleeve yielded such that desired torque was not achieved; shaft was shaved.
- SS sleeve on SS shaft - small chips.
- SS sleeve on Al. shaft - shaft chipped by sleeve, especially with tighter fits and hardened sleeves.
- For sleeve (D) (tapered bore), the engagement decreased as sleeve slipped on shaft.

E. RESULTS OF SIGNIFICANT TESTS

Following the unsuccessful preliminary tests, sleeve designs were devised which differ from that in the proposal in an attempt to arrive at a workable sleeve; they are shown in Figure 2, H through K. Also, several different setting shaft configurations were tested with these sleeves, as given in Figure 4, E through J.

A workable sleeve should have a gradient of torque VS engagement of about 1 in.-lb. per .010 in. of engagement at a nominal engagement that would position the sleeve in approximately the same location on the shaft as is occupied by the present grip rings, and, at the same time, provide a slipping torque of 9 to 13 in.-lb.

Many pages of test data and plots accumulated throughout these tests. However, to minimize the pages in this report, only some representative sample data sheets are presented; a complete file of data is preserved at the contractor's facility.

E.1 Log of Tests

A detailed log of the 82 sleeve tests done during this phase of testing is presented on the following five pages. The log shows test number and date, sleeve design, material and inside diameter, shaft shape, material and outside diameter, references to data sheets and plot sheets, and notes. The letter appearing in Column 12, Notes, refers to the sleeve and shaft designs defined in Figures 1 to 4.

TEST LOG FOR CLUTCH SLEEVE SH'T TL-1

G. ROLAND

8-7-81 TEST LOG FOR CLUTCH SLEEVE M577 FUZE

①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪	⑫		⑬	⑭
TEST NO.	TEST DATE	SLEEVE					SHAFT				NOTES		DATA SHEET	PLOT SHEET
		NUMBER	DW'G NUMBER	MAT'L	BORE	SLEEVE CONFIG'N	DW'G NUMBER	MAT'L	O.D.	SHOULDER CONFIG.	SLEEVE	SHAFT	NUMBER	NUMBER
01	7/15/81	1	SK003	7075 T4/T6	.220	6 SEGM'TS	SK005	7075 T4/T6	.222	SQUARE	H (2)	D	6-18	6-21,22
02		2			.218	"					H (2)	D		
03	↓	3	↓	↓	.216	"	↓	↓	↓	↓	H (2)	D	↓	↓
04	7/27/81	4-1	SK003-A	7075 T4/T6	.212	"	SK005	7075 T4/T6	.222	SQUARE	H (1)	D	6-26	6-28
05	↓	4-2	↓	↓	.212	"	SK006	↓	↓	15° CHAMF.	H (2)	E	6-27	↓
06	7/28/81	5-1	SK003-A	7075 T4/T6	.202	"	SK005	7075 T4/T6	.222	SQUARE	H (2)	D	6-29	6-31
07	↓	5-2	↓	↓	.202	"	SK006	↓	↓	15° CHAMF.	H (2)	E	6-30	↓
08	NOT DONE	6-1	SK003-A	7075 T4/T6	TOO SMALL TO FIT SHAFT	"	SK005	7075 T4/T6	.222	SQUARE	H (2)	D	6-32	—
09	7/28/81	6-2	↓	↓	.192	"	SK006	↓	↓	15° CHAMF.	H (2)	E	6-33	6-34
10	8/6/81	7	SK007	7075 T4/T6	.218	4 SEGM'TS	SK006	7075 T4/T6	.222	15° CHAMF.	I	E	4-13	4-29,30,31
11		8	SK007		.214	"					I	E	4-14	4-22
12		9		↓	.210	"					I	E	4-15	4-23
13		10		STAINLESS 420	.218	"					(1) I	E	4-16	4-24
14		11			.214	"					(1) I	E	4-17	4-25
15	↓	12	↓	↓	.210	"	↓	↓	↓	↓	(1) I	E	4-18	4-26
16	8/7/81	7	SK007	7075 T4/T6	.218	"	SK006	7075 T4/T6	.222	15° CHAMF.	I	E	4-19	4-19,30,31
17		8			.214	"					I	E	4-20	4-22
18	↓	9	↓	↓	.210	"	↓	↓	↓	↓	I	E	4-21	4-23
19	9/8/81	13	SK-007-A	7075 T4/T6	.218	"	SK-006-A	7075 T4/T6	.222	15° CHAMF.	(2) I	E	4-32	4-38

(1) NOT HARDENED (2) TUMBLED

TEST LOG FOR CLUTCH SLEEVE

SH'T TL-2

G. ROLAND

8-7-81

TEST LOG FOR CLUTCH SLEEVE

M577 FUZE

①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪	⑫		⑬	⑭
TEST NO.	TEST DATE	SLEEVE					SHAFT				NOTES		DATA SHEET	PLOT SHEET
		NUMBER	DW'G NUMBER	MAT'L	BORE	SLEEVE CONFIG'N	DW'G NUMBER	MAT'L	O.D.	SHOULDER CONFIG.	SLEEVE	SHAFT	NUMBER	NUMBER
20	9/8/81	14	SK007-A	7075 T4/T6	.214	4 SEGMENTS	SK006-A	7075 T4/T6	.222	15° CHAMFER	(2) I	E	4-33	4-39
21		15		↓	.210	"					(2) I	E	4-34	4-40
22		16		STAINLESS 420	.218	"					(1)(2) I	E	4-35	4-41
23		17			.214	"					(1)(2) I	E	4-36	4-42
24	↓	18	↓	↓	.210	"	↓	↓	↓	↓	(1)(2) (3) I	E	4-37	4-43
25	9/8/81	A	5891	STAINLESS 416	.219	TAPERED C-SHAPE	SK006-A	7075 T4/T6	.222	15° CHAMFER	(2) B	E	T-1	T-2
26	9/8/81	E	5891	STAINLESS 416	.217	"					(2) B	E	T-3	T-4
27	9/10/81	E				"					(2) B	E	T-3	T-4
28	9/10/81	E	↓	↓	↓	"	↓	↓	↓	↓	(2) B	E	T-3	T-4
29	9/11/81	A	5891	STAINLESS 416	.219	"	SK006-A	7075 T4/T6	.222	15° CHAMFER	(2) B	E	T-1	T-2
30	9/14/81	19	SK007-A	7075 T4/T6	.218	4 SEGMENTS	SK008	7075 T4/T6	.222	2° TAPER	I	F	4-44	4-50
31		20			.214	"				.330 FROM END	I	F	4-45	4-51
32	↓	21	↓	↓	.210	"	↓	↓	↓	↓	I	F	4-46	4-52
33	9/15/81	19	SK007-A	7075 T4/T6	.218	"	SK009	7075 T4/T6	.222	2° TAPER	I	G	4-47	4-50
34		20			.214	"				.250 FROM END	I	G	4-48	4-51
35	↓	21	↓	↓	.210	"	↓	↓	↓	↓	I	G	4-49	4-52
36	9/21/81	22	SK007-A	7075 T4/T6	.218	"	SK010	7075 T4/T6	.222	1° TAPER	I	H	4-53	4-56
37	9/22/81	23			.214	"				.250 FROM END	I	H	4-54	4-57
38	↓	24	↓	↓	.210	"	↓	↓	↓	↓	I	H	4-55	4-58

(1) NOT HARDENED (2) TUMBLED (3) SLEEVE CRACKED (4) HARD COATED

G. ROLAND

8-7-81

TEST LOG FOR CLUTCH SLEEVE

TEST LOG FOR CLUTCH SLEEVE

SH'T TL-3

M577 FUZE

①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪	⑫		⑬	⑭
TEST NO.	TEST DATE	SLEEVE					SHAFT				NOTES		DATA SHEET	PLOT SHEET
		NUMBER	D'W'G NUMBER	MAT'L	BORE	SLEEVE CONFIG'N	D'W'G NUMBER	MAT'L	O.D.	SHOULDER CONFIG.	SLEEVE	SHAFT	NUMBER	NUMBER
39	10/2/81	25	SK007-A	STAINLESS 420	.218	4 SEGMENTS	SK011	7075 T4/T6	.222	1° TAPER	(1) I	(4) H	4-59	4-62
40	10/5/81	26	↓	↓	.214	"	↓	↓	↓	.250 FROM END ↓	(1) I	(4) H	4-60	4-63
41	10/6/81	27			.210	"					(1) I	(4) H	4-61	4-64
42	10/8/81	22T	5891	7075 MADE ON SCREW MACH.	.214 +	TAPERED C-SHAPE	SK011	7075 T4/T6	.222	1° TAPER	B	(4) H	T-5	T-6
43	10/8/81	22T	↓	↓	.214+	"	↓	↓	↓	.250 FROM END ↓	B	H	T-7	T-8
44	10/13/81	10T	5891	7075 T4/T6	.215	"	SK011	7075 T4/T6	.222		B	H	T-9	T-10
45	10/13/81	G	5891	STAINLESS 416 RC33-38	.215	"	SK011	7075 T4/T6	.222		(2) B	H	T-11	T-12
46	10/14/81	B	5891	↓	.219	"	SK011	7075 T4/T6	.222		(2) B	H	T-13	T-14
47	10/14/81	C	5891		.219	"	SK011	7075 T4/T6	.222		(2) B	(4) H	T-15	T-16
48	10/16/81	28	SK007-A	STAINLESS 416 ~~RC35~~	.218	4 SEGMENTS	SK011	7075 T4/T6	.222		(2) I (3)	(4) H	4-65	NOT PLOTTED SLEEVE CRACKED
49	10/16/81	29	SK007-A	STAINLESS 416 RC35	.214	4 SEGMENTS	SK011	7075 T4/T6	.222		(3) I	(4) H	4-66	NO TEST 2 SEGMENTS BROKE OFF
50	10/16/81	41	SK017	7075 T4/T6	.218	SOLID-1	SK011	7075 T4/T6	.222		J	(4) H	S-1	S-2
51	10/21/81	H	5891	STAINLESS 416 RC33-38	.215	TAPERED C-SHAPE	SK011	7075 T4/T6	.222	↓	(2) B	(4) H	T-17	T-18
52	10/22/81	46	SK020	7075 T4/T6	.220	SOLID-2	SK010	7075 T4/T6	.222	.148° TAPER	K	(5) I	S-3	S-4
53	11/19/81	45	SK020	STAINLESS 416 RC34-38	.213	SOLID-2	SK019	7075 T4/T6	.222	1° TAPER .520 FROM END	K	(4) J	S-5	S-6
54	11/19/81	44	SK020	STAINLESS 416 RC34-38	.218	SOLID-2	SK019	7075 T4/T6	.222	.5° TAPER .520 FROM END	K	(4) J	S-7	S-8
55	11/20/81	43	SK020	STAINLESS 416 RC34-38	.220	SOLID-2	SK019	7075 T4/T6	.222	.25° TAPER .520 FROM END	K	(4) J	S-9	S-10
56	11/25/81	48	SK020	7075 T4/T6	.213	SOLID-2	SK019	7075 T4/T6	.222	1° TAPER .520 FROM END	K	(4) J	S-11	S-12
57	11/30/81	47	SK020	7075 T4/T6	.218	SOLID-2	SK019	7075 T4/T6	.222	.5° TAPER .520 FROM END	K	(4) J	S-13	S-14

(1) NOT HARDENED (2) TUMBLED (3) HARDENED TO RC52-56 TOO HARD! (4) HARD COATED (5) SEE SHEET S-3 FOR EXPLANATION OF SHAFT TAPER

TEST LOG FOR CLUTCH SLEEVE — SH'T TL-4

G. ROLAND

8-7-81

TEST LOG FOR CLUTCH SLEEVE — M577 FUZE

① TEST NO.	② TEST DATE	③ SLEEVE NUMBER	④ SLEEVE DWG NUMBER	⑤ SLEEVE MAT'L	⑥ SLEEVE BORE	⑦ SLEEVE CONFIG'N	⑧ SHAFT DWG NUMBER	⑨ SHAFT MAT'L	⑩ SHAFT O.D.	⑪ SHOULDER CONFIG.	⑫ NOTES SLEEVE	⑫ NOTES SHAFT	⑬ DATA SHEET NUMBER	⑭ PLOT SHEET NUMBER
58	12/8/81	51	SK020	7075 T4/T6	.220	SOLID-2	SK010	7075 T4/T6	.222	1° TAPER .250° FROM END	K	H	S-15	S-16
59	12/9/81	52	SK020	7075 T4/T6	.217	SOLID-2	SK010	7075 T4/T6	.222	"	K	H	S-17	S-18
60	12/10/81	46	SK020	7075 T4/T6	.220	SOLID-2	SK010	7075 T4/T6	.222	.148° TAPER	K	(5) I	S-19	S-4
61	12/11/81	55	SK021	7075 T4/T6	.220	SOLID-2	58089	7075 T4/T6	.222	STRAIGHT	K	A	S-20	S-21
62	12/15/81	54	SK021	7075 T4/T6	.221	SOLID-2	SK022 #8	7075 T4/T6	.222	.143° TAPER	K	I	S-22	S-24
63	12/29/81	68	SK021	7075 T4/T6	.221	SOLID-2	SK022 #9	7075 T4/T6	.222	.143° TAPER	K	I	S-23	S-24
64	1/5/82	69	SK021	7075 T4/T6	.221	SOLID-2	SK022 #10	7075 T4/T6	.222	.143° TAPER	K	I	S-25	S-24
65	1/5/82	70	SK021	7075 T4/T6	.221	SOLID-2	SK022 #11	7075 T4/T6	.222	.143° TAPER	K	I	S-26	S-24
66	1/6/82	71	SK021	7075 T4/T6	.221	SOLID-2	SK022 #12	7075 T4/T6	.222	.143° TAPER	K	I	S-27	S-24
67	1/7/82	72	SK021	7075 T4/T6	.221	SOLID-2	SK022 #13	7075 T4/T6	.222	.143° TAPER	K	I	S-28	S-24
68	1/13/82	54	SK021	7075 T4/T6	.221	SOLID-2	SK022 #8	7075 T4/T6	.222	.143° TAPER	K	(6) I	S-22	S-24
69	1/13/82	68	SK021	7075 T4/T6	.221	SOLID-2	SK022 #9	7075 T4/T6	.222	.143° TAPER	K	(6) I	S-23	S-24
70	1/13/82	69	SK021	7075 T4/T6	.221	SOLID-2	SK022 #10	7075 T4/T6	.222	.143° TAPER	K	(6) I	S-25	S-24
71	1/13/82	70	SK021	7075 T4/T6	.221	SOLID-2	SK022 #11	7075 T4/T6	.222	.143° TAPER	K	(6) I	S-26	S-24
72	1/13/82	71	SK021	7075 T4/T6	.221	SOLID-2	SK022 #12	7075 T4/T6	.222	.143° TAPER	K	(6) I	S-27	S-24
73	1/13/82	72	SK021	7075 T4/T6	.221	SOLID-2	SK022 #13	7075 T4/T6	.222	.143° TAPER	K	(6) I	S-28	S-24
74	1/14/82	68	SK021	7075 T4/T6	.221	SOLID-2	SK022 #9	7075 T4/T6	.222	.143° TAPER	K	(6) I	S-29	—
75	1/14/82	69	SK021	7075 T4/T6	.221	SOLID-2	SK022 #10	7075 T4/T6	.222	.143° TAPER	K	(6) I	S-29	—
76	1/14/82	70	SK021	7075 T4/T6	.221	SOLID-2	SK022 #11	7075 T4/T6	.222	.143° TAPER	K	(6) I	S-29	—

(4) HARD COATED

(5) SEE SHEET S-[illegible] FOR EXPLANATION OF SHAFT TAPER FOR THIS TEST ONLY (6) IN PARTLY ASSEMBLED FUZE

G. ROLAND

8-7-81

TEST LOG FOR CLUTCH SLEEVE

SH'T TL-5

TEST LOG FOR CLUTCH SLEEVE

M577 FUZE

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)		(13)	(14)
TEST NO.	TEST DATE	SLEEVE					SHAFT				NOTES		DATA SHEET	PLOT SHEET
		NUMBER	D'W'G NUMBER	MAT'L	BORE	SLEEVE CONFIG'N	D'W'G NUMBER	MAT'L	O.D.	SHOULDER CONFIG.	SLEEVE	SHAFT	NUMBER	NUMBER
77	1/15/82	71	SK021	7075 T4/T6	.221	SOLID-2	SK022 #12	7075 T4/T6	.222	.143° TAPER	K	(6) I	S-29	—
78	1/15/82	72	SK021	7075 T4/T6	.221	SOLID-2	SK022 #13	7075 T4/T6	.222	.143° TAPER	K	(6) I	S-29	—
79	1/27/82	73	SK021	7075 T4/T6	.221	SOLID-2	SK022 #21	7075 T4/T6	.222	.143° TAPER	K	(6) I	S-30,31	S-32
80	1/28/82	74	SK021	7075 T4/T6	.221	SOLID-2	SK022 #22	7075 T4/T6	.222	.143° TAPER	(7) K	(6) I	S-33,34	
81	1/29/82	75	SK021	7075 T4/T6	.221	SOLID-2	SK022 #23	7075 T4/T6	.222	.143° TAPER	K	(6) I	S-35,36	
82	1/29/82	76	SK021	7075 T4/T6	.221	SOLID-2	SK022 #24	7075 T4/T6	.222	.143° TAPER	(7) K	(6) I	S-37,38	

(6) IN PARTLY ASSEMBLED FUZE (7) SLEEVE & SHAFT LUBRICATED

E.2 Six-segment Sleeve

The next sleeve tested was a six-segment design, Figure 2(H), in which each segment behaved as a cantilever beam with a concentrated load where the segments contacted the shaft. Several interference fits were tried, and the farther the sleeve was pressed onto the shaft, the more each segment bent, thereby increasing the grip and the resistance to turning.

Before testing, some theoretical calculations were made to get a feel for the torque that a segmented sleeve could transmit, and the stresses that would be developed in the segment with each segment behaving as a cantilever beam. Theoretical curves of Torque vs Engagement for several values of coefficient of static friction are plotted in Figure 5.

Test data points for three values of sleeve/shaft interference from Page 23 are superimposed on Figure 5. Notice that the torque follows the theory curve up to abcut $x = .16$, at which point torque does not increase with engagement at the same rate as shown theoretically. In an effort to increase the Torque vs Engagement gradient, sleeves with greater interference were tested; Figure 6 is a plot of that data from Pages 25 and 26. These data exhibit the same torque characteristics as that in Figure 5 and, also, some tendency for torque to drop off is evident at high engagements. Some yielding of the segments was found by measuring the O.D. of the free end of the sleeve, which indicates high stresses at the fixed end of the segment. Figure 7 is a plot of the theoretical bending stress for one cantilever segment as a function of engagement for three levels of sleeve/shaft interference. It is apparent that stress levels can exceed the allowable for aluminum for engagements over 50% of segment length, even at low interference levels, and the test data confirms this.

It is also of interest to note the values of the coefficient of static friction on the curves of Figures 5 and 6 in the vicinity of the test points; Mark's "Handbook" values of f-static for aluminum on aluminum are given as 1.05, whereas the test data falls at lower values.

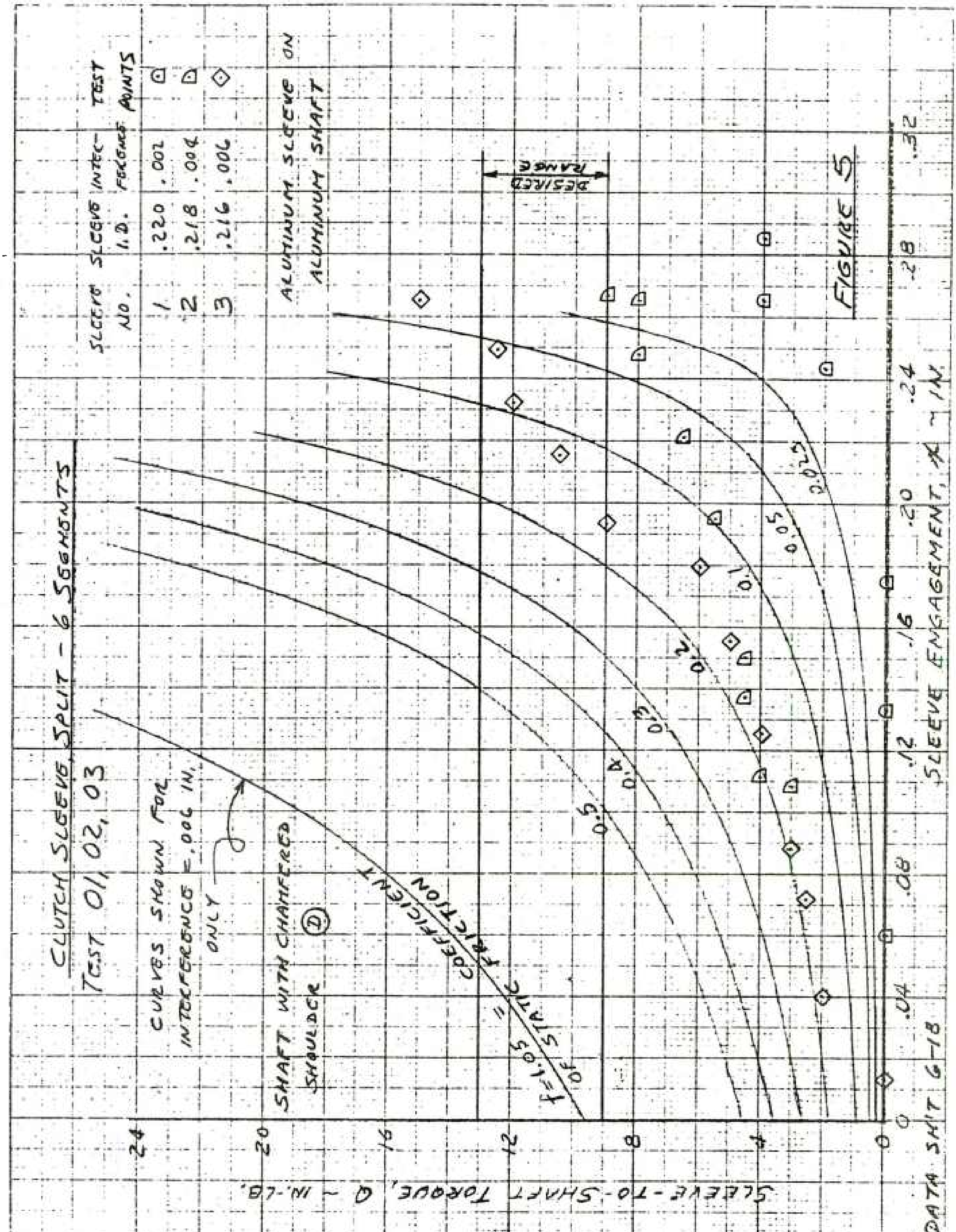
S. [illegible]
7-15-81
PLOT SH'T 6-21,22

CLUTCH SLEEVE, SPLIT - 6 SEGMENTS
TEST : 1, 2, 3 TORQUE VS ENGAGEMENT
MAT'L : ALUMINUM 7075 T4/T6

SH'T 6-18
DW'G SK003
M577 FUZE

1	2	3	4	5	6	7	8	9	10
TEST NO.	SLEEVE NO.	SLEEVE I.D.	SLEEVE-TO-SHAFT DIST.	TORQUE	SHOULDER LENGTH	DIST. + LENGTH	SLEEVE ENGAGE'M'T	INTER-FERENCE	SHAFT CONFIG.
	—	IN.	IN.	IN-LB	IN.	IN.	IN.	IN.	—
	—	GIVEN	MEASURED	MEASURED	GIVEN	4 + 6	.465 - 7	.222 - 3	ALUM.
01	1	.220	.205	0	.200	.405	.060	.002	SQUARE SHOULDER
			.132	0		.332	.133		
			.090	0		.290	.175		
			.022	2		.222	.243		
			0	4		.200	.265		
			-.020	4		.180	.285		
02	2	.218	.157	3		.357	.108	.004	
			.154	4		.354	.111		
			.128	4.5		.328	.137		
			.115	4.5		.315	.150		
			.070	5.5		.270	.195		
			.044	6.5		.244	.221		
			.0175	8.0		.2175	.2475		
			0	8.0		.200	.265		
			-.0015	9.0		.1985	.2665		
03	3	.216	.252	0		.452	.013	.006	
			.225	2		.425	.040		
			.193	2.5		.393	.072		
			.177	3		.377	.088		
			.140	4		.340	.125		
			.110	5		.310	.155		
			.086	6		.286	.179		
			.072	9		.272	.193		
			.050	10.5		.250	.215		
			.033	12		.233	.232		
			.016	12.5		.216	.249		
			0	15		.200	.265		

G. ROLAND 7-15-81



G. R LAND — CLUTCH SLEEVE, SPLIT - 6 SEGMENT — SH'T 6-26

7-27-81 — TEST : TORQUE VS. ENGAGEMENT — D'WG SK003-A

PLOT SH'T 6-28 — MAT'L : ALUMINUM 7075 T4/T6 — M577 FUZE

(1) TEST NO.	(2) SLEEVE NO.	(3) SLEEVE I.D.	(4) SLEEVE-TO SHAFT DIST.	(5) TORQUE	(6) SHOULDER LENGTH	(7) DIST. + LENGTH	(8) SLEEVE ENGAGEMENT	(9) INTER-FERENCE	(10) SHAFT CONFIG.
	—	IN.	IN.	IN.-LB.	IN.	IN.	IN.	IN.	—
	—	FROM SH'T 6-23 @ (8)	MEASURED	MEASURED	GIVEN	(4) + (6)	.465-(7)	.222-(3)	ALUM.
04	4-1	.21114	.235	1.5	.200	.435	.030	.01086	SK005
		.21120	.219	1.5		.419	.046	.01080	SQUARE SHOULDER
		.21129	.198	2.5		.398	.067	.01071	
		.21138	.174	2.5		.374	.091	.01062	
		.21147	.150	3.5		.350	.115	.01053	
		.21154	.133	3.5		.333	.132	.01046	
		.21162	.111	4.0		.311	.154	.01038	
		.21178	.070	7.0		.270	.195	.01022	
		.21178	.070(1)	5.0		.270	.195	.01022	
		.21186	.050	7.0		.250	.215	.01014	
		.21192	.034	8.0		.234	.231	.01008	
		.21192	.034(1)	8.0		.234	.231	.01008	
		.21200	.014	8.0		.214	.251	.01000	
		.21206	.000	10.5		.200	.265	.00994	
		.21210	-.012	11.0		.188	.277	.00990	
		.21216	-.028	13.0		.172	.293	.00984	

NOMINAL INTERFERENCE = .010 IN.

NOMINAL SLEEVE I.D. = .212 IN.
HOWEVER, THE I.D. TAPERS AS SHOWN ON SHEET 6-23.
WE THINK THIS HAPPENED BECAUSE THE SLOTS WERE CUT WITH A SAW RUNNING AT A HIGHER RPM THAN WAS DONE FOR SLEEVES NO. 1, 2, & 3.

(1) SLEEVE BACKED OFF DURING PREVIOUS TORQUE MEASUREMENT

G. ROLANO — CLUTCH SLEEVE, SPLIT- 6 SEGMENTS — SH'T 6-27

7-27-81 — TEST : TORQUE VS. ENGAGEMENT — D'W'G SK003-A

PLOT SH'T 6-28 — MAT'L : ALUMINUM 7075 T4/T6 — M577 FUZE

1	2	3	4	5	6	7	8	9	10
TEST NO.	SLEEVE NO.	SLEEVE I.D.	SLEEVE-TO SHAFT DIST.	TORQUE	SHOULDER LENGTH	DIST. + LENGTH	SLEEVE ENGAGEMENT	INTER-FERENCE	SHAFT CONFIG.
	—	IN.	IN.	IN.-LB	IN.	IN.	IN.	IN.	—
	—	FROM SH'T 6-23 @ 8	MEASURED	MEASURED	GIVEN	4 + 6	.465 - 7	.222 - 3	ALUM.
05	4-2	.21116	.230	1.5	.200	.430	.035	.01084	SK006
		.21128	.199	2.0		.399	.066	.01072	CHAMF. SHOULDER
		.21143	.160	3.0		.360	.105	.01057	
		.21155	.129	5.0		.329	.136	.01045	
		.21165	.105	6.0		.305	.160	.01035	
		.21171	.090	6.5		.290	.175	.01029	
		.21177	.073	7.5		.273	.192	.01023	
		.21184	.055	9.0		.255	.210	.01016	
		.21179	.068 (1)	8.0		.268	.197	.01021	
		.21180	.037	10.5		.237	.228	.01020	
		.21203	.007	13.0		.207	.258	.00997	
		.21205	.000	13.5		.200	.265	.00995	
		.21212	-.018	15.0		.182	.283	.00988	

NOMINAL INTERFERENCE = .010 IN

NOM. SLEEVE I.D. = .212 IN

SEE NOTE ON SHEET 6-26

(1) SEE NOTE P. 6-26

G. ROLAND 7-27-81

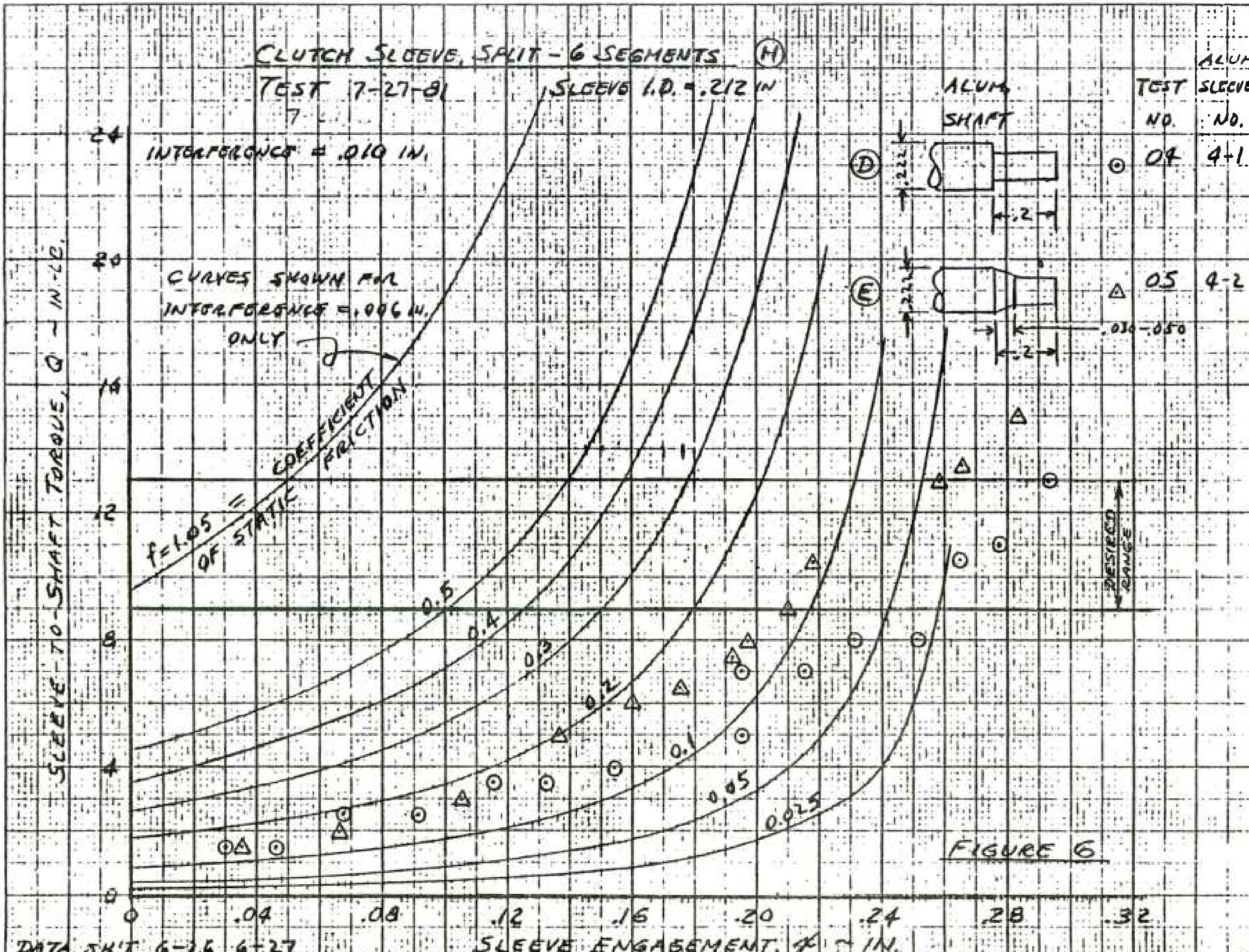
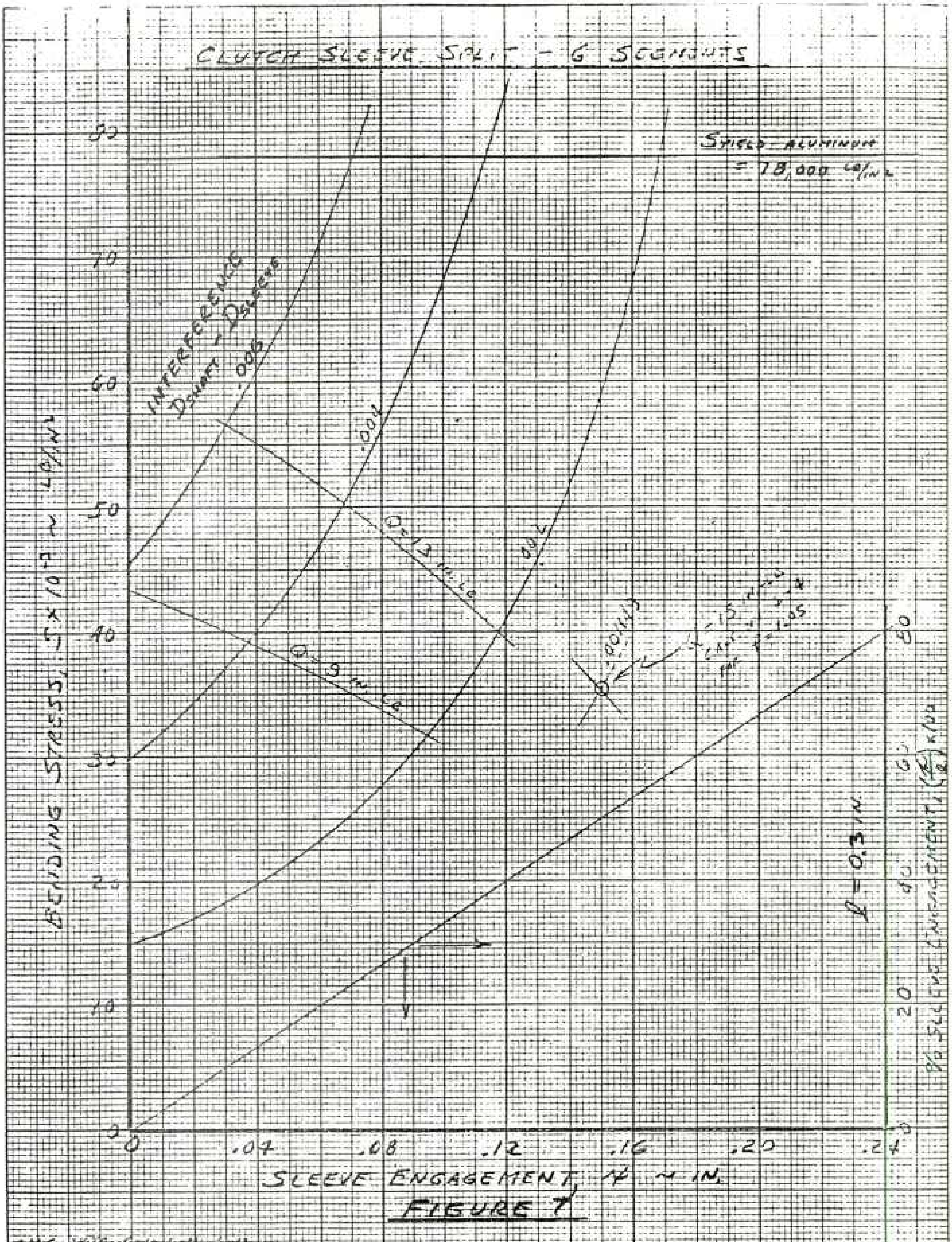


FIGURE 6


CLUTCH SLEEVE SPLIT - 6 SEGMENTS
BENDING STRESS
SLEEVE ENGAGEMENT ~ IN.
INTERFERENCE
.006
.004
.002
= 78,000
0
.04
.08
.12
.16
.20
.24
10
20
30
40
50
60
70
80
20
40
60
80
FIGURE 7

E.3 Four-segment Sleeve

In order to improve the gradient of Torque vs Engagement, a design having four segments was adopted because each individual segment is larger, and therefore stiffer, and would be expected to develop higher torque, for the same engagement, than the six-segment design. That did happen, as Figure 8 shows; Test 11 data has a steeper gradient and higher torque, for the same engagement, than the six-segment sleeve. Test 17 was done with the same sleeve and shaft. It, too, shows a good gradient, but the data did not match Test 11. This lack of repeatability was typical of the four-segment aluminum sleeve and aluminum shaft.

Figures 9, 10, and 11 show test data for a stainless steel sleeve on a shouldered aluminum shaft. Three different interference fits were tried - .004, .008, and .012 in. Each shows a good gradient, but the two tighter fits were too high and the inside edges of the segments cut the shaft.

Figures 12, 13, and 14 are test data plots for 1° and 2° tapered shafts. There is some slightly better repeatability, but high engagement was required to achieve the desired torque of 9 to 13 in.-lb. The data in Figure 14 for a stainless sleeve on a 1° tapered shaft (Figure 4 H) shows the same trends, and also exhibits some walk-off as the sleeve turned. These plots are typical, and tighter fits on the steel sleeve resulted in even higher walk-off.

G.R. 8-6-81

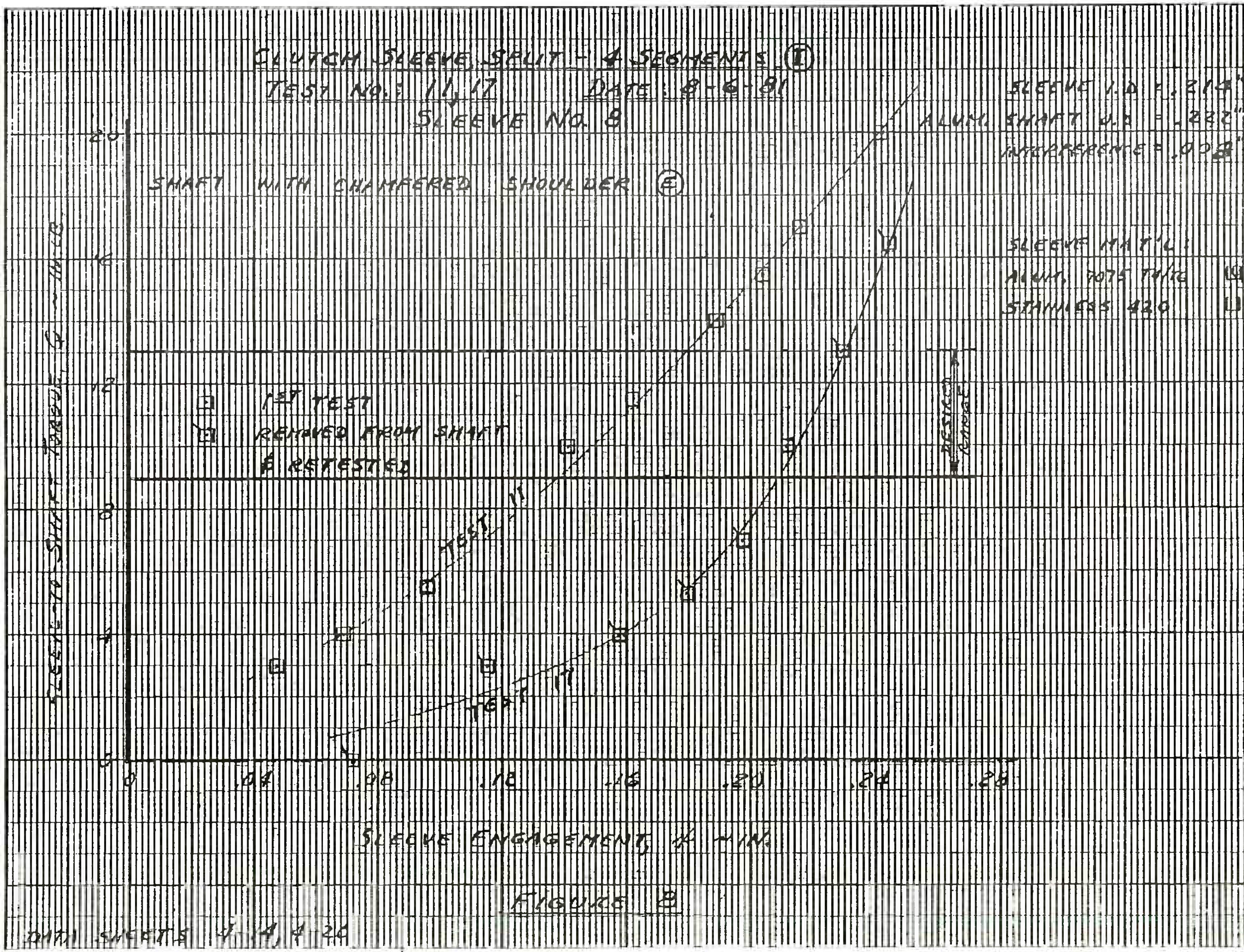


FIGURE 8

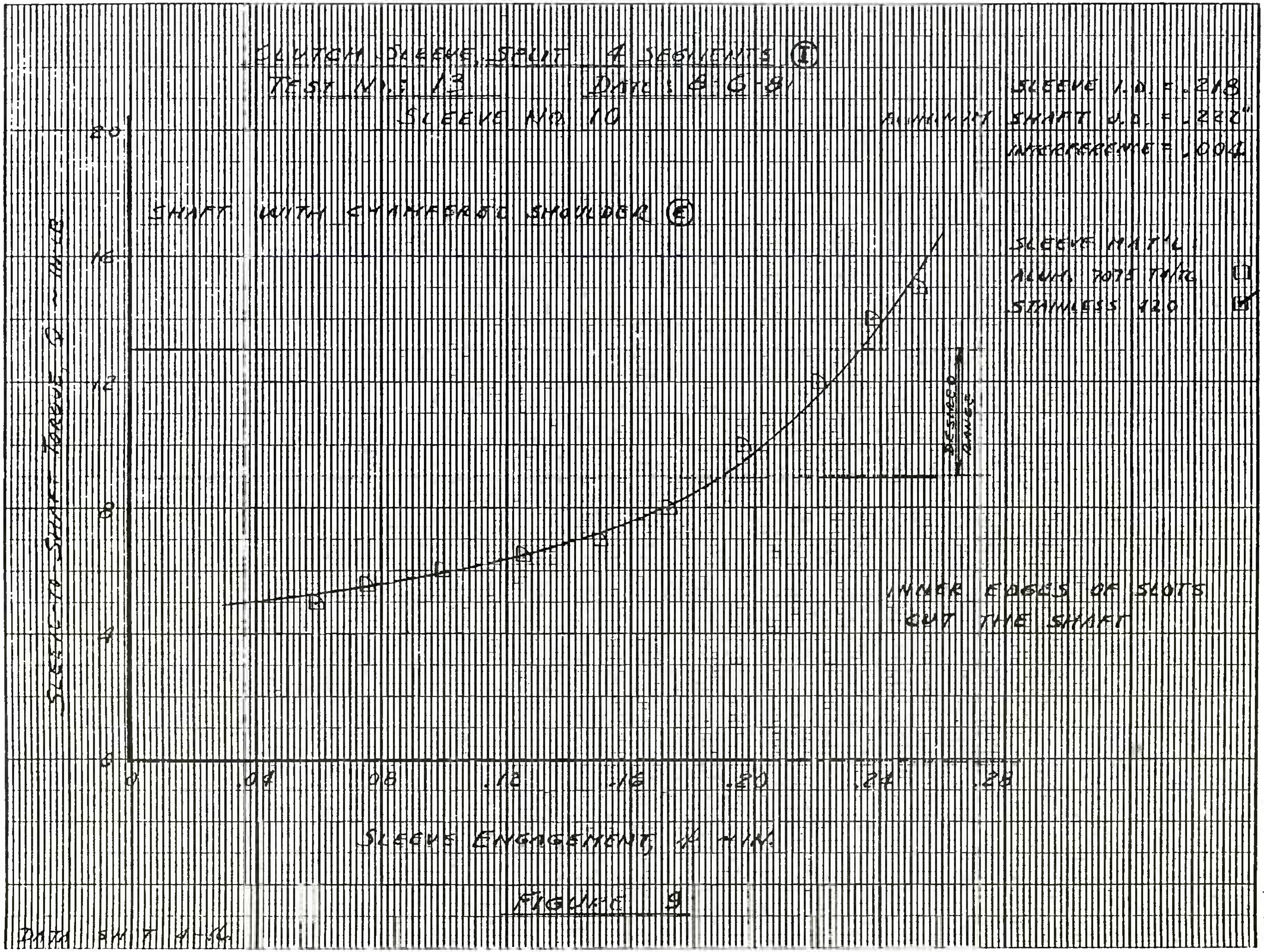
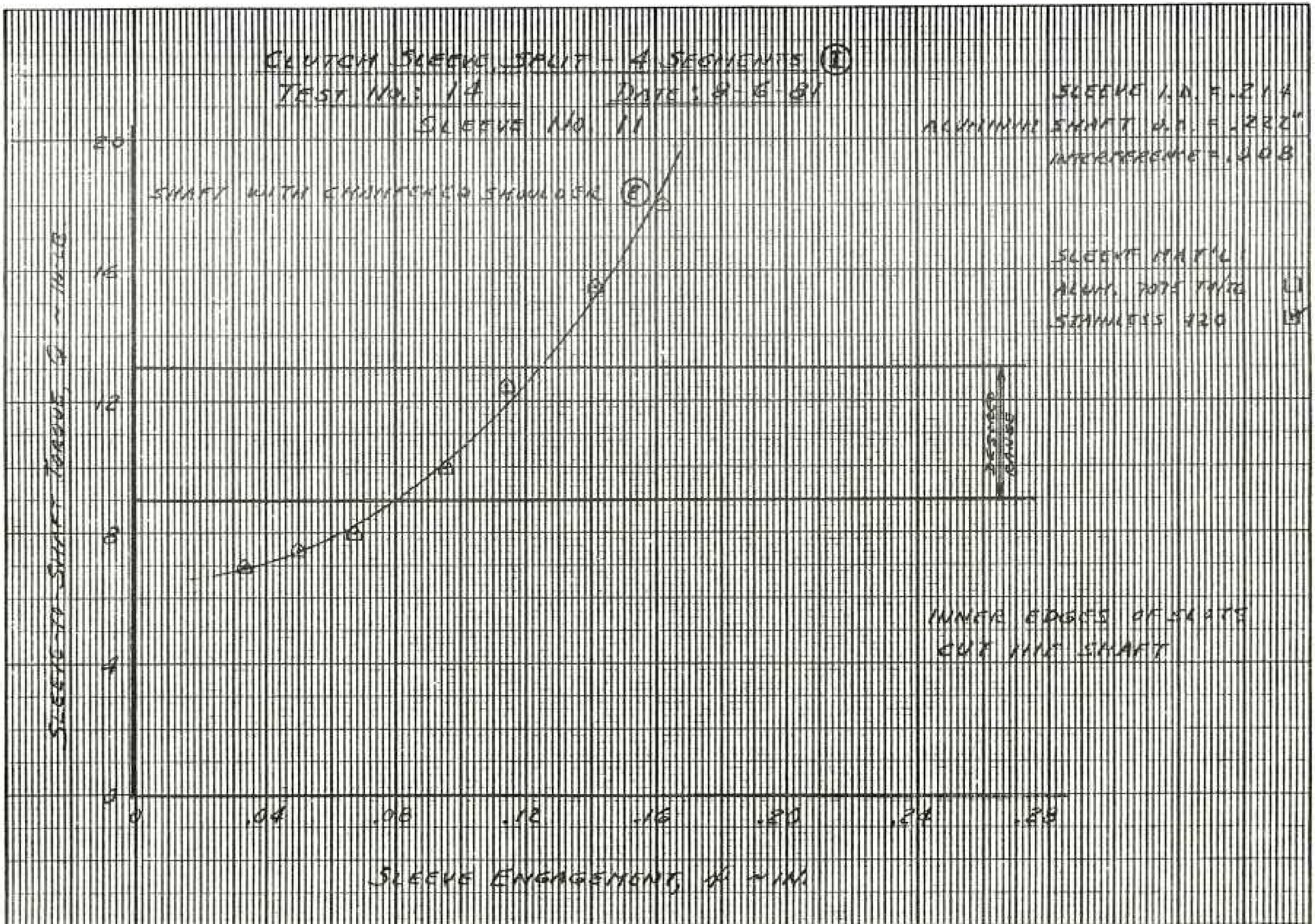
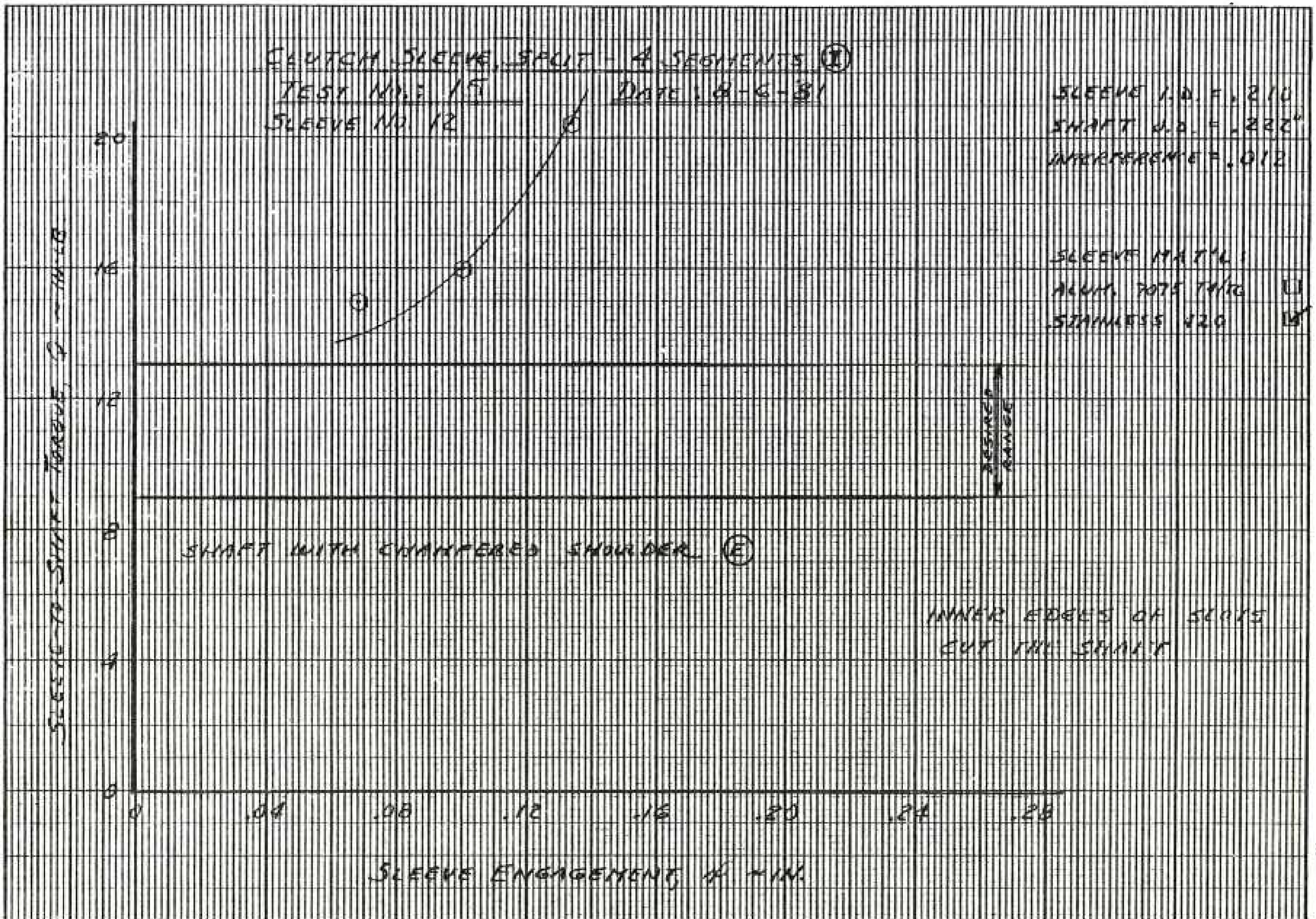

CLUTCH SLEEVE, SPLIT 4 SEGMENTS (I)
TEST NO.: 13
DATE: 6-6-81
SLEEVE NO. 10
SLEEVE I.D. = .218
ALUMINUM SHAFT O.D. = .222"
INTERFERENCE = .004
SHAFT WITH CHAMFERED SHOULDER (E)
SLEEVE MAT'L
ALUM. 7075 T6/G
STAINLESS 420
DESIRED RANGE
INNER EDGES OF SLOTS CUT THE SHAFT
SLEEVE-TO-SHAFT TORQUE, Q ~ IN-LB
SLEEVE ENGAGEMENT, A ~ IN.
0
.04
.08
.12
.16
.20
.24
.28
4
8
12
16
20
DATA SH'T 4-16
SH'T 4-27

FIGURE 9



CLUTCH SLEEVE SPLIT - 4 SEGMENTS
TEST NO.: 14
DATE: 8-6-81
SLEEVE NO. 11
SLEEVE I.D. = .214
ALUMINUM SHAFT O.D. = .222"
INTERFERENCE = .008
SHAFT WITH CHAMFERED SHOULDER
SLEEVE MAT'L:
ALUM. 7075 T6/T6
STAINLESS 420
DESIRED RANGE
INNER EDGES OF SLATS CUT INTO SHAFT
0
4
8
12
16
20
0
.04
.08
.12
.16
.20
.24
.28
SLEEVE TO SHAFT TORQUE, Q ~ IN-LB
SLEEVE ENGAGEMENT, X ~ IN.
DATA SH'T 4-17

FIGURE 10


CLUTCH SLEEVE, SPLIT - 4 SEGMENTS (I)
TEST NO.: 15
DATE: 8-6-81
SLEEVE NO. 12
SLEEVE I.D. = .210
SHAFT O.D. = .222"
INTERFERENCE = .012
SLEEVE MAT'L:
ALUM. 7075 T4/TG
STAINLESS 420
DESIRED RANGE
SHAFT WITH CHAMFERED SHOULDER (E)
INNER EDGES OF SLOTS CUT THE SHAFT
SLEEVE-TO-SHAFT TORQUE, Q ~ IN-LB
SLEEVE ENGAGEMENT, ℓ ~ IN.
0
4
8
12
16
20
.04
.08
.12
.16
.20
.24
.28
DATA SH'T 4-18
FIGURE 11

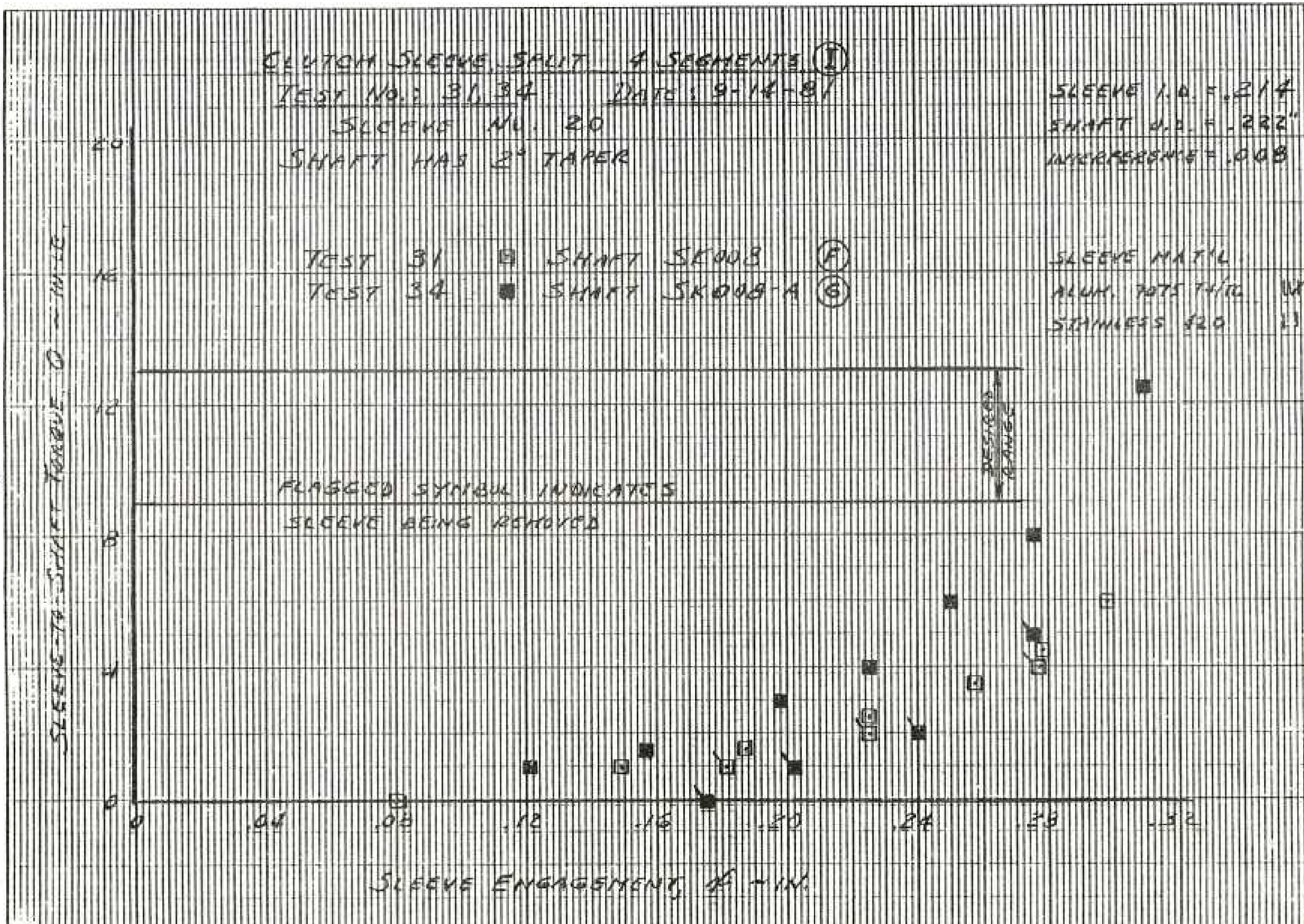

CLUTCH SLEEVE SPLIT 4 SEGMENTS (I)
TEST NO.: 31, 34 DATE: 9-14-81
SLEEVE NO. 20
SHAFT HAS 2° TAPER
TEST 31 SHAFT SK008 (F)
TEST 34 SHAFT SK008-A (G)
SLEEVE I.D. = .214
SHAFT O.D. = .222"
INTERFERENCE = .008
SLEEVE MAT'L
ALUM. 7075 T4/T6
STAINLESS 420
DESIRED RANGE
FLAGGED SYMBOL INDICATES
SLEEVE BEING REMOVED
SLEEVE-TO-SHAFT TORQUE Q ~ IN-LB
SLEEVE ENGAGEMENT, ℓ ~ IN.
0
4
8
12
16
20
0
.04
.08
.12
.16
.20
.24
.28
.32
DATA SHT 4-45, 4-48

FIGURE 12

4-

4-57

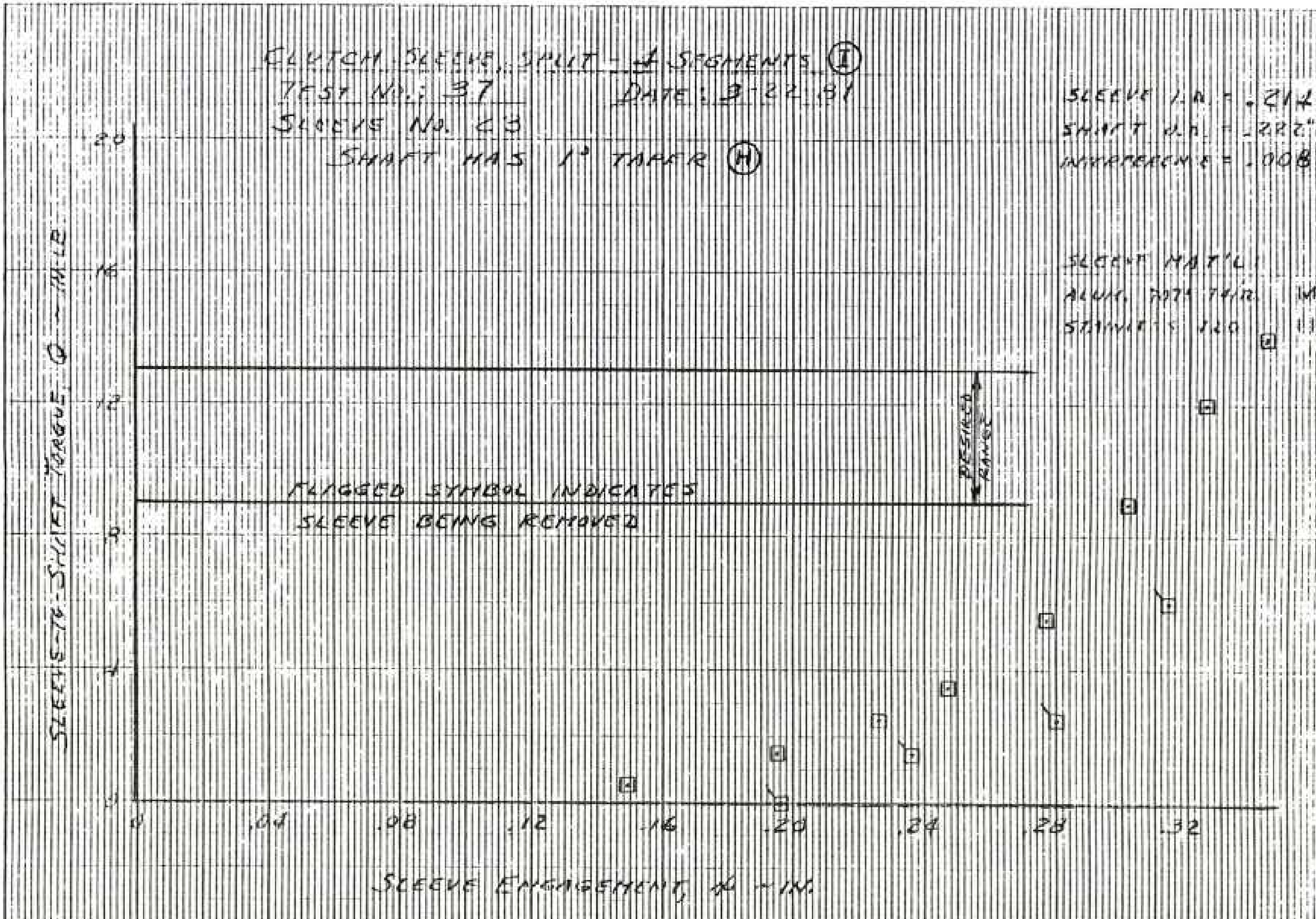


FIGURE 13

10-2-81

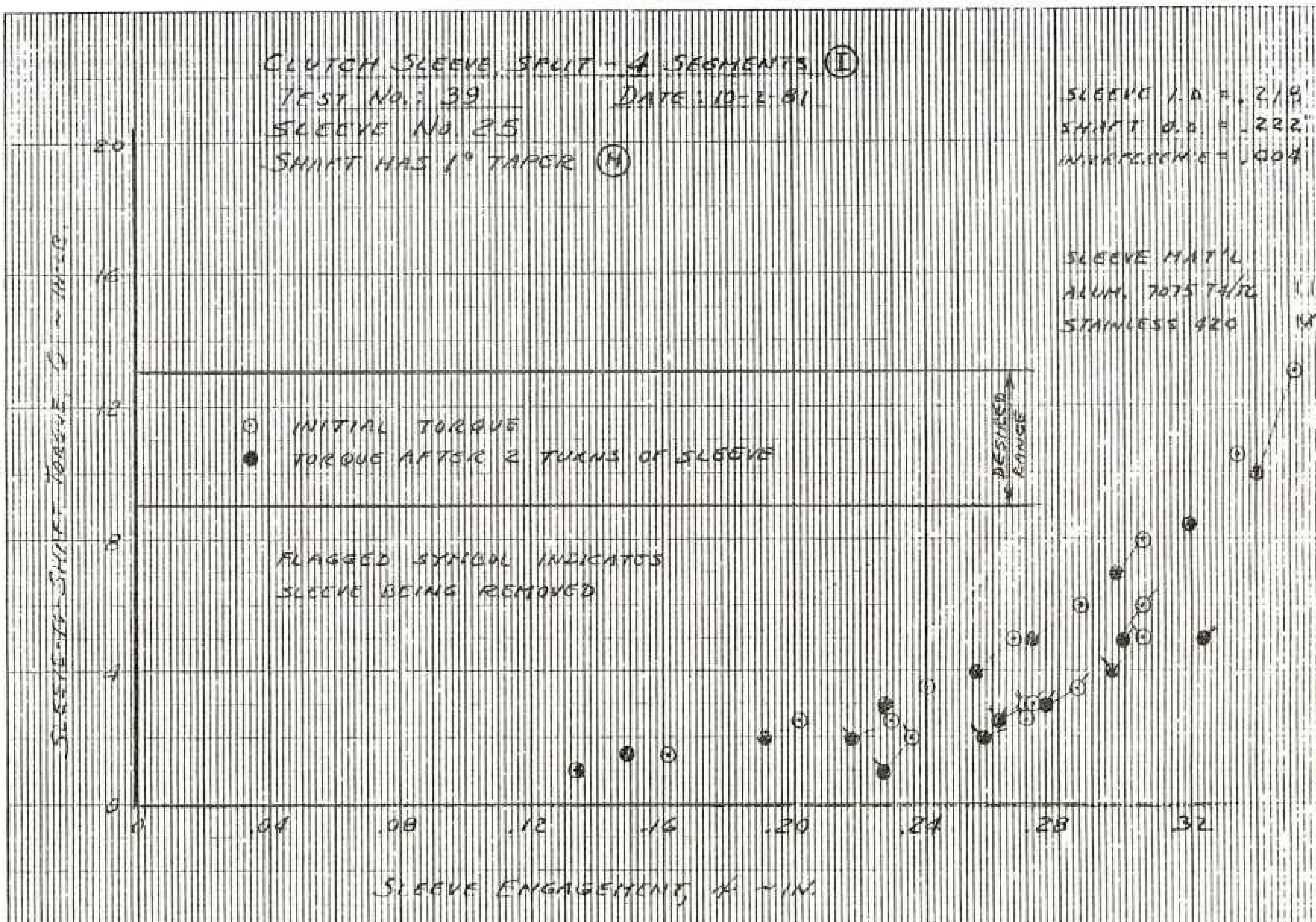


FIGURE 14

4-52

E.4 Tapered C-Shape Sleeve

A modification of the C-shape sleeve first suggested in the HTI proposal was tested concurrently with tests of the segmented sleeves. This design, B in Figure 1, had been looked at in the preliminary tests which did not bear fruit, but it was felt that a second look was warranted to verify its performance.

This cylindrical sleeve was tapered at one end, thereby reducing its stiffness compared to a straight sleeve. Such a design should increase its grip on the shaft as it is pressed on, in proportion to the increase in wall thickness with taper. Figures 15 and 16 show test results for this sleeve made of stainless steel heat treated to RC-33 to -38 on a shouldered shaft, E in Figure 4, for two different interference fits. In both figures, the gradient of the data is quite flat, even though the torque is higher at any engagement for the tighter fit. Also, the hard sleeve chipped the shoulder of the shaft.

Figures 17 through 20 show test data for these sleeves on 1^{o} tapered shafts, Figure 4 H. Figure 17 depicts data for an aluminum sleeve on a hard-coated aluminum shaft at .008 in. interference. The torque barely reaches 9 in.-lb. and the gradient flattens at high engagement indicating yielding of the sleeve. Figure 18 shows data for an aluminum sleeve on a plain aluminum shaft at .007 in. interference; the gradient is also flat, and the torques are about the same. Figure 19 shows data for a stainless steel sleeve on a hard-coated aluminum shaft at .003 in. interference. Again, we have a very low gradient and do not achieve the desired torque at this low interference fit. Figure 20 shows the same sleeve and shaft combination at a tighter fit of .007 in.;

yet, again, we find a low gradient, though somewhat greater torque. In all four of these examples, walk-off of the sleeve was a problem after two turns, the greatest being with the hardened steel sleeve on a hard-coated shaft.

Some aluminum sleeves used in these and other tests of C-shaped sleeves were made by hand, and others on automatic screw machines. These sleeves did not always perform the same, probably because, as examination showed, the inside surface finishes were different.

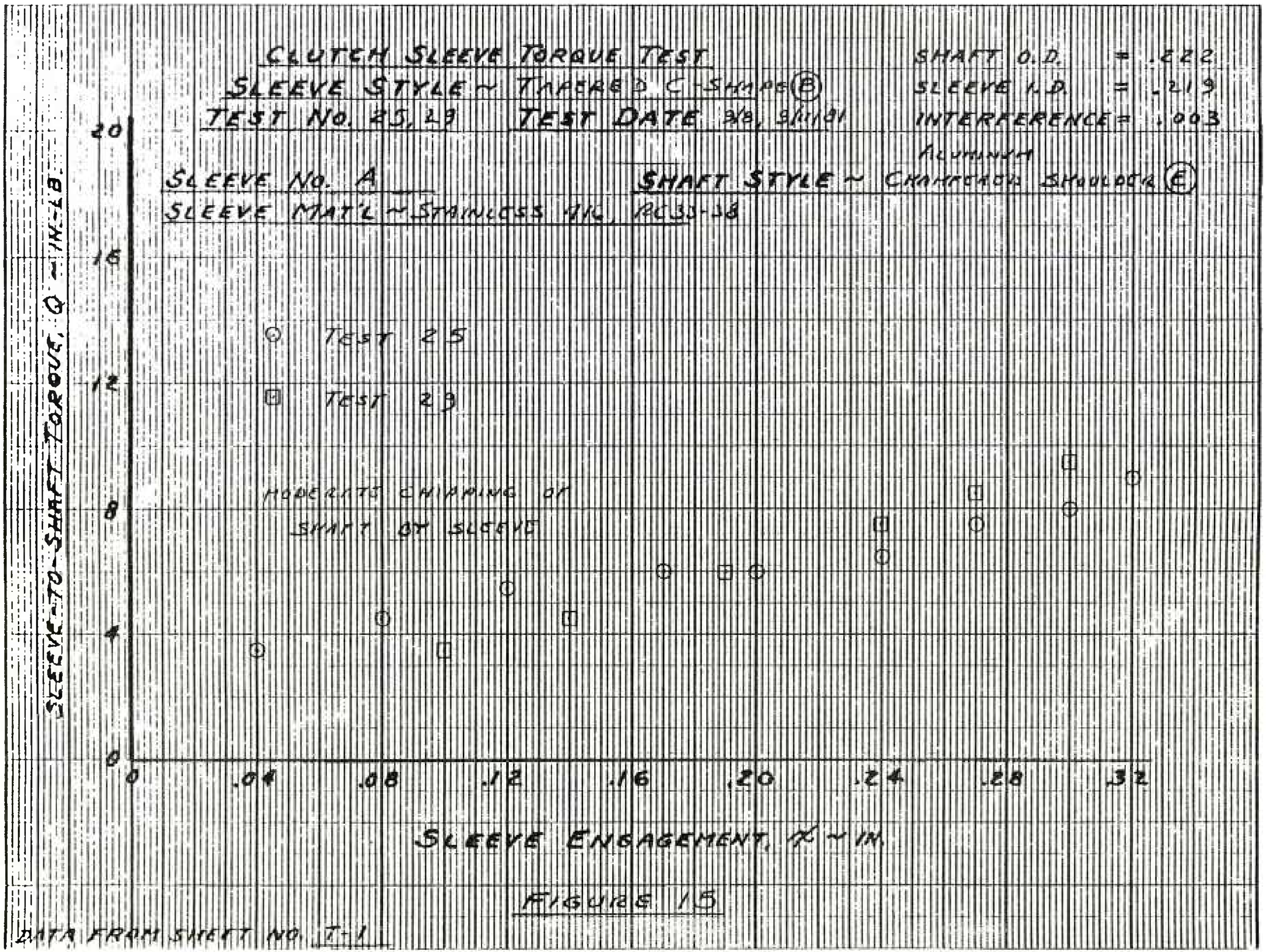

CLUTCH SLEEVE TORQUE TEST
SLEEVE STYLE ~ TAPERED C-SHAPE (B)
TEST No. 25, 29
TEST DATE 3/8, 3/11/81
SHAFT O.D. = .222
SLEEVE I.D. = .219
INTERFERENCE = .003
SLEEVE No. A
SLEEVE MAT'L ~ STAINLESS 416, RC33-38
SHAFT STYLE ~ ALUMINUM CHAMFERED SHOULDER (E)
TEST 25
TEST 29
MODERATE CHIPPING OF SHAFT BY SLEEVE
SLEEVE-TO-SHAFT TORQUE, Q ~ IN-LB
0
4
8
12
16
20
.04
.08
.12
.16
.20
.24
.28
.32
SLEEVE ENGAGEMENT, X ~ IN.
DATA FROM SHEET NO. T-1

FIGURE 15

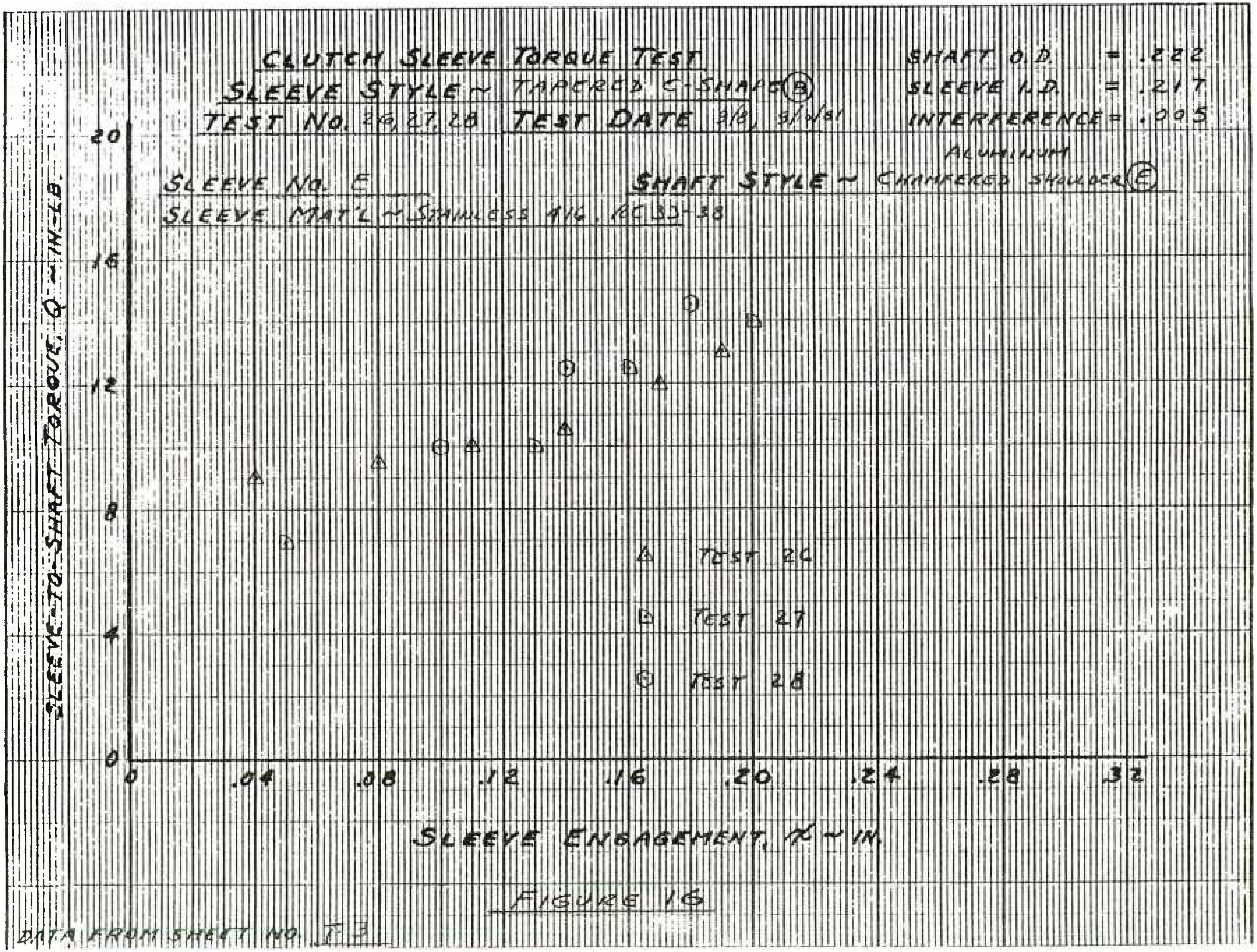

CLUTCH SLEEVE TORQUE TEST
SLEEVE STYLE ~ TAPERED C-SHAFT (B)
TEST No. 26, 27, 28
TEST DATE 3/8, 3/10/81
SHAFT O.D. = .222
SLEEVE I.D. = .217
INTERFERENCE = .005
ALUMINUM
SLEEVE No. E
SHAFT STYLE ~ CHAMFERED SHOULDER (E)
SLEEVE MAT'L ~ STAINLESS 416, RC 33-38
TEST 26
TEST 27
TEST 28
SLEEVE-TO-SHAFT TORQUE, Q ~ IN-LB
SLEEVE ENGAGEMENT, X ~ IN.
0
4
8
12
16
20
.04
.08
.12
.16
.20
.24
.28
.32
DATA FROM SHEET NO. T-3

FIGURE 16

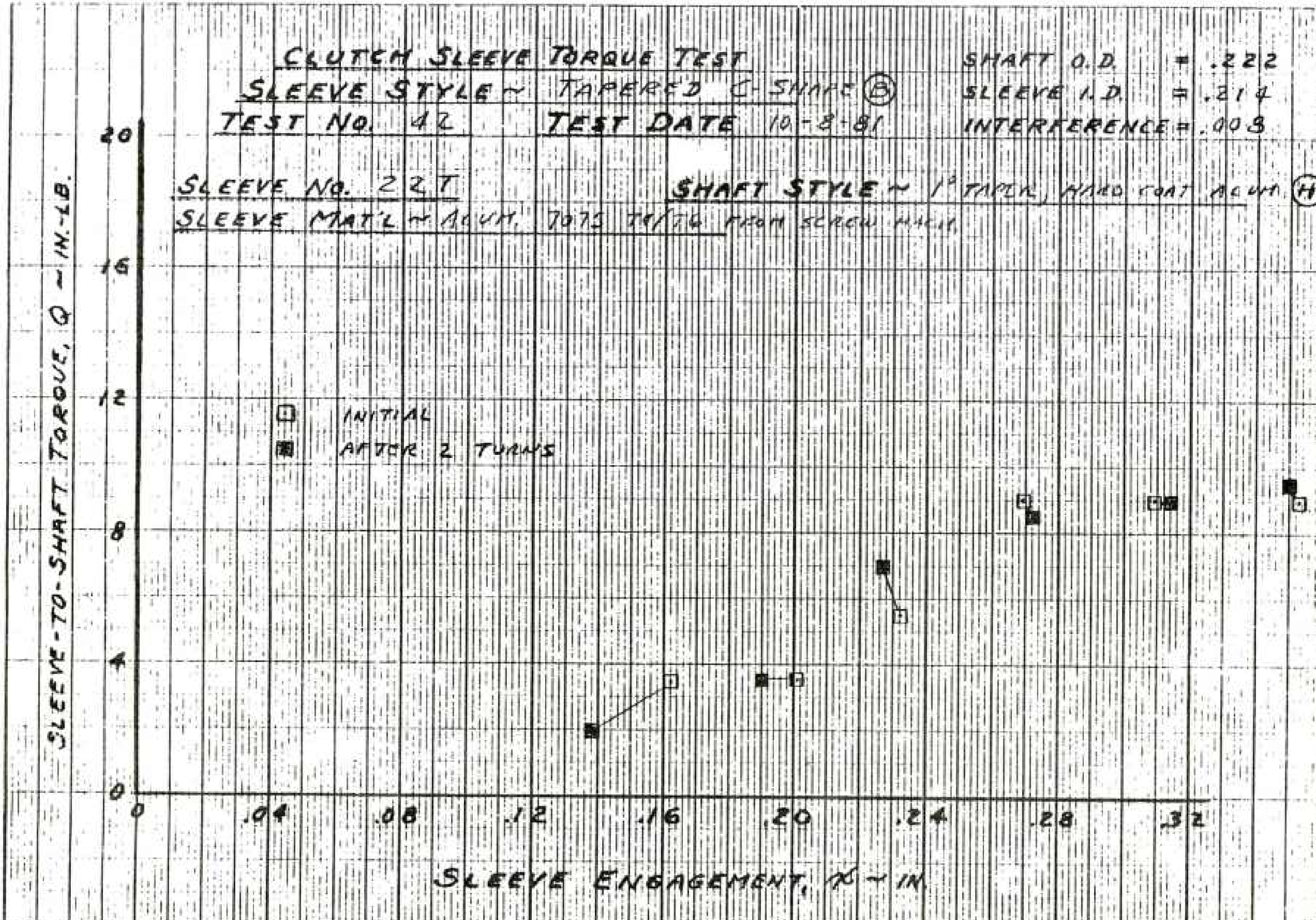

CLUTCH SLEEVE TORQUE TEST
SLEEVE STYLE ~ TAPERED C-SHAPE (B)
TEST NO. 42
TEST DATE 10-8-81
SHAFT O.D. = .222
SLEEVE I.D. = .214
INTERFERENCE = .008
SLEEVE NO. 22T
SLEEVE MAT'L ~ ALUM. 7075 T6/T6 FROM SCREW MACH.
SHAFT STYLE ~ 1° TAPER, HARD COAT ALUM (H)
INITIAL
AFTER 2 TURNS
SLEEVE-TO-SHAFT TORQUE, Q ~ IN.-LB.
0
4
8
12
16
20
.04
.08
.12
.16
.20
.24
.28
.32
SLEEVE ENGAGEMENT, X ~ IN
DATA FROM SHEET NO. T-5

FIGURE 17

G.R. 10-20 81

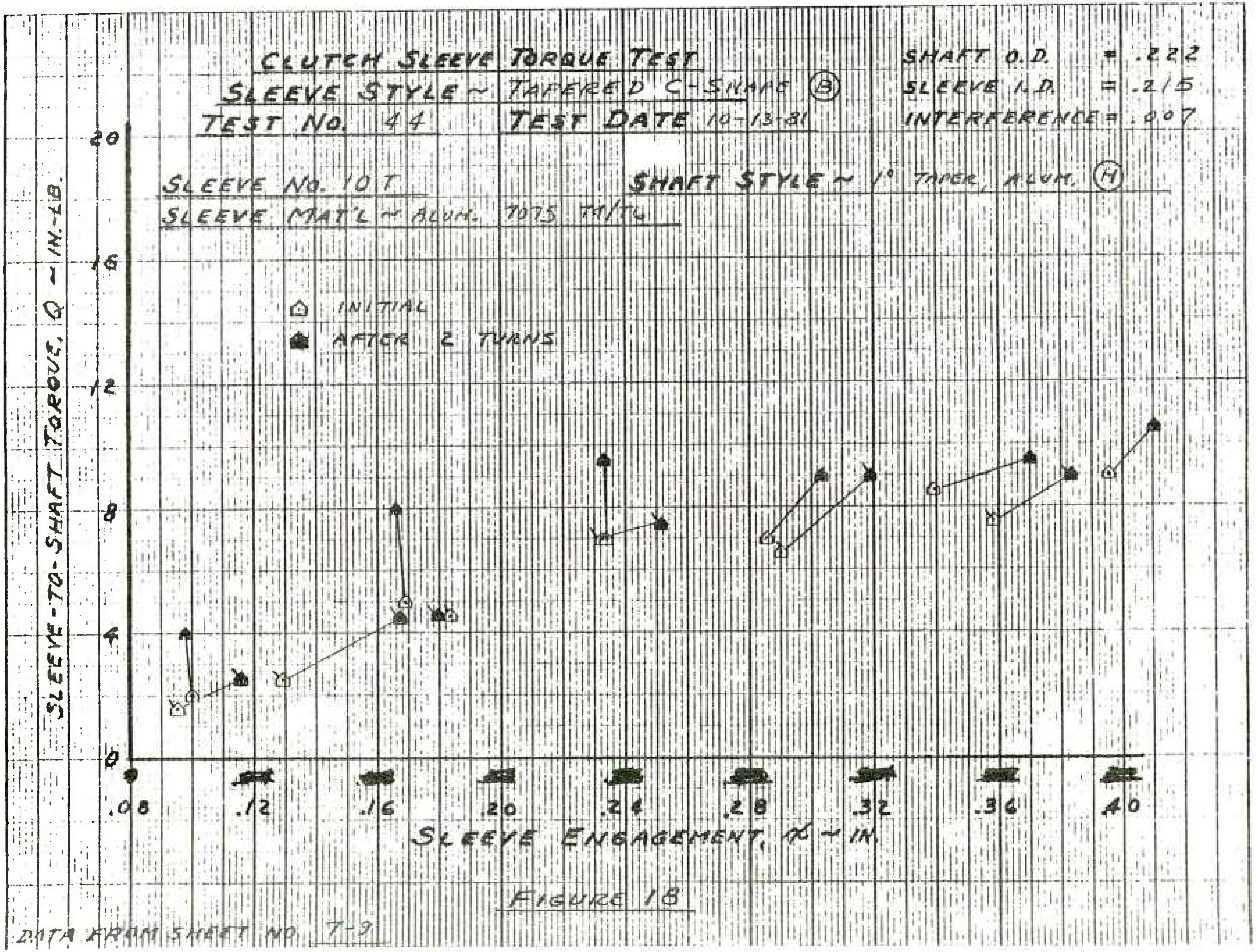


FIGURE 18

T-10

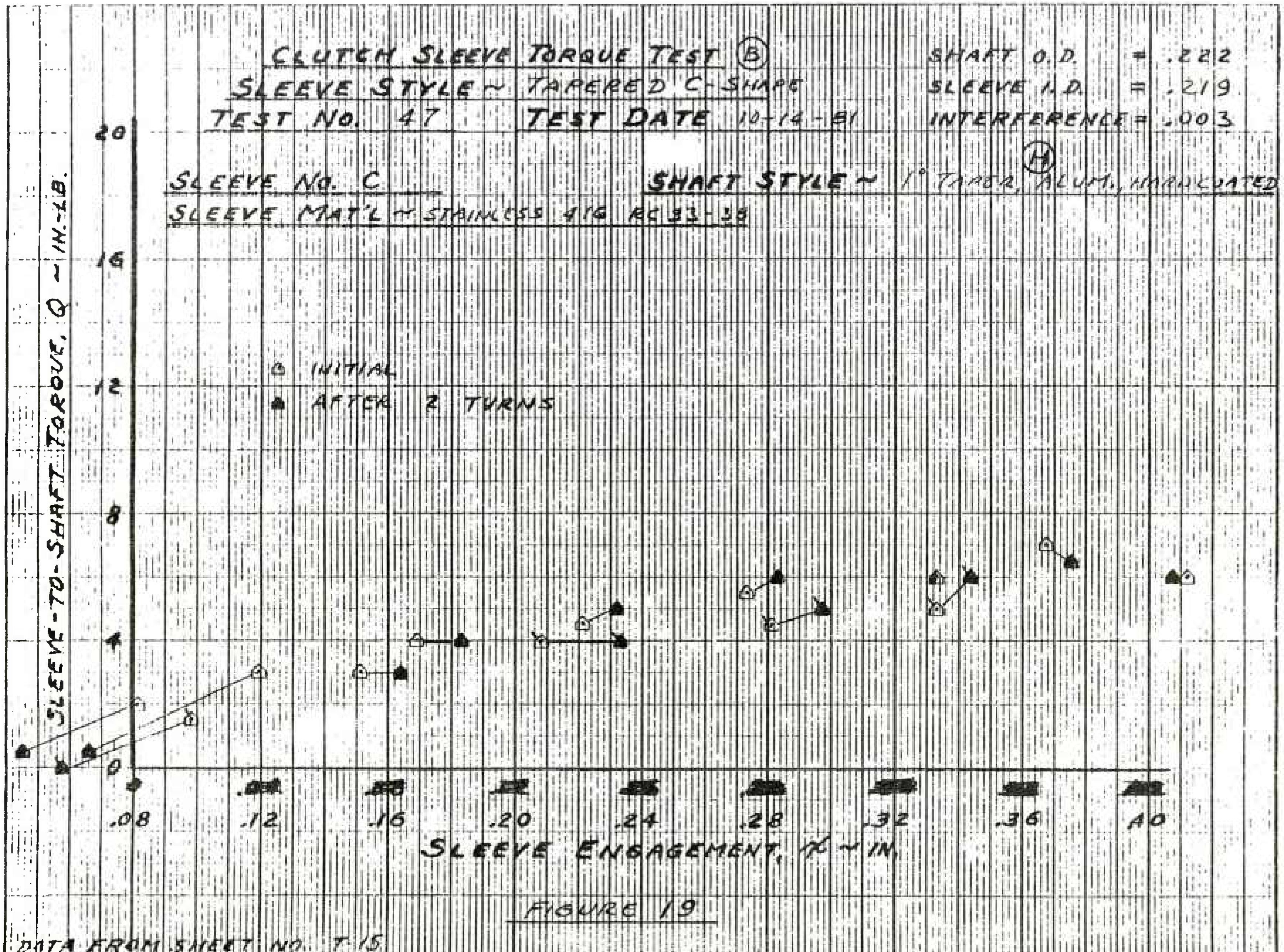

CLUTCH SLEEVE TORQUE TEST (B)
SLEEVE STYLE ~ TAPERED C-SHAPE
TEST NO. 47
TEST DATE 10-14-81
SHAFT O.D. = .222
SLEEVE I.D. = .219
INTERFERENCE = .003
SLEEVE NO. C
SHAFT STYLE ~ 1° TAPER, ALUM., UNLUBRICATED (H)
SLEEVE MAT'L ~ STAINLESS 416 RC 33-38
INITIAL
AFTER 2 TURNS
SLEEVE-TO-SHAFT TORQUE, Q ~ IN-LB.
20
16
12
8
4
0
.08
.12
.16
.20
.24
.28
.32
.36
.40
SLEEVE ENGAGEMENT, X ~ IN.
DATA FROM SHEET NO. T-15

FIGURE 19

G.R. 10-21-81

T 18

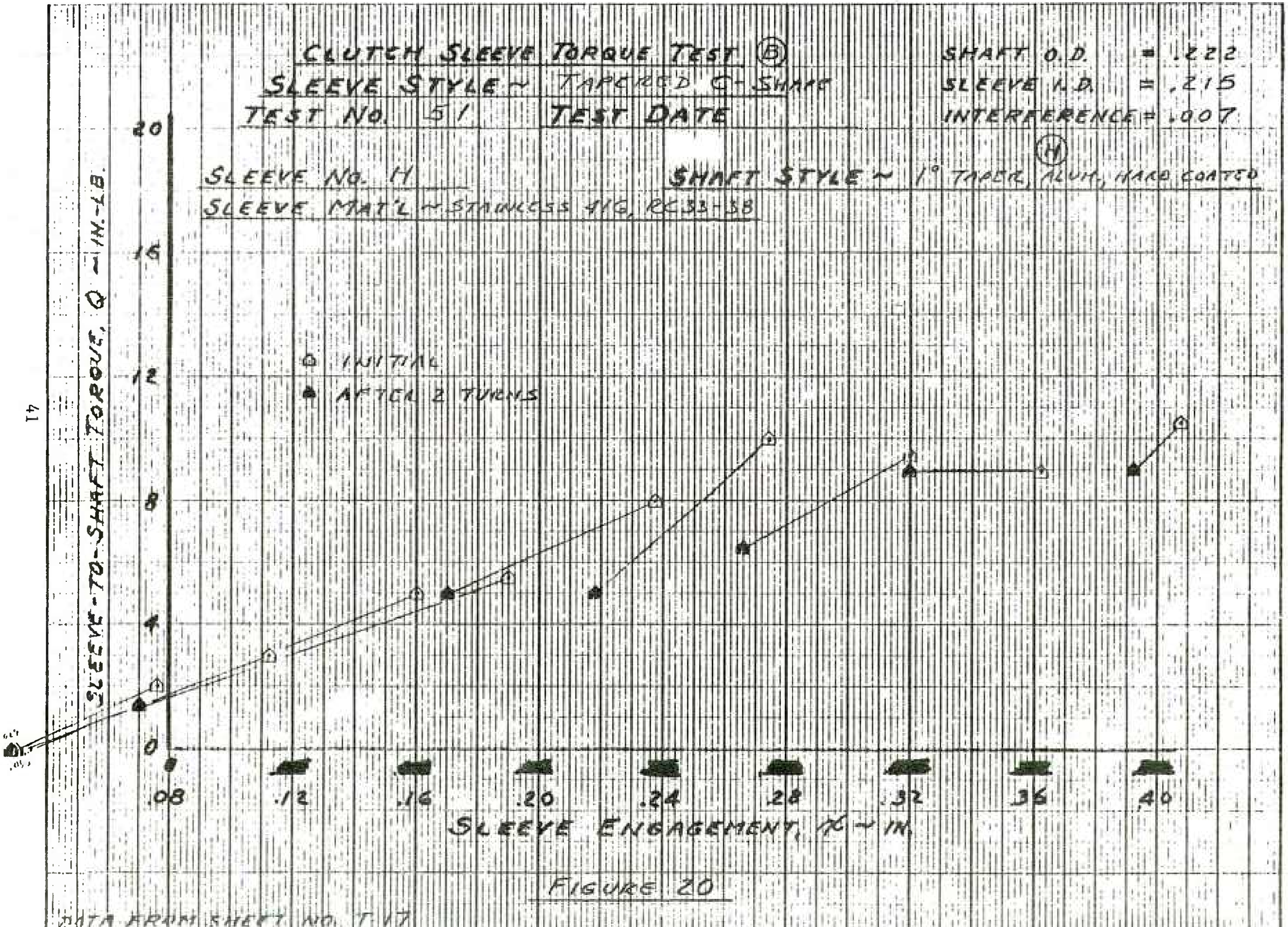


FIGURE 20

E.5 Solid Cylindrical Sleeve

The general approach to this program has been to go in the direction indicated by the test data. Since the fingered sleeves did not give repeatable data because of yielding of the fingers, and since the C-shape sleeve torque gradient was low, the next move was to find a design that would be stiff enough not to yield and, at the same time, develop the desired torque. Accordingly, a solid cylindrical sleeve was designed, made and tested.

First, a sleeve with a single drive slot, Figure 2 J, was tried on a 1° tapered shaft, Figure 4 H, using a setting key having but one drive tab. This single-tab key failed at 12 in.-lb. torque, Test 50.

A second drive slot was then added to the sleeve so it could be used with the existing setting key having two drive tabs. See Figure 2 K. This design, in aluminum, was tested beginning with Test 52 using what was intended to be a hard-coated aluminum shaft having a 1° taper at .002 in. interference. Results were encouraging as shown by the data on Figure 21.

Next, a stainless steel sleeve was tried on hard-coated aluminum shafts of 1°, 0.5°, and 0.25° tapers, Figure 4 J. Interference was reduced as taper was reduced, being .009, .004, and .002 in. respectively, Tests 53-55. The torque/engagement gradients in these tests were high - two to three, or more in.-lb. per .010 in.; walk-off was also noticeable at 1° taper.

GR 11-19-'81
12-11-'81

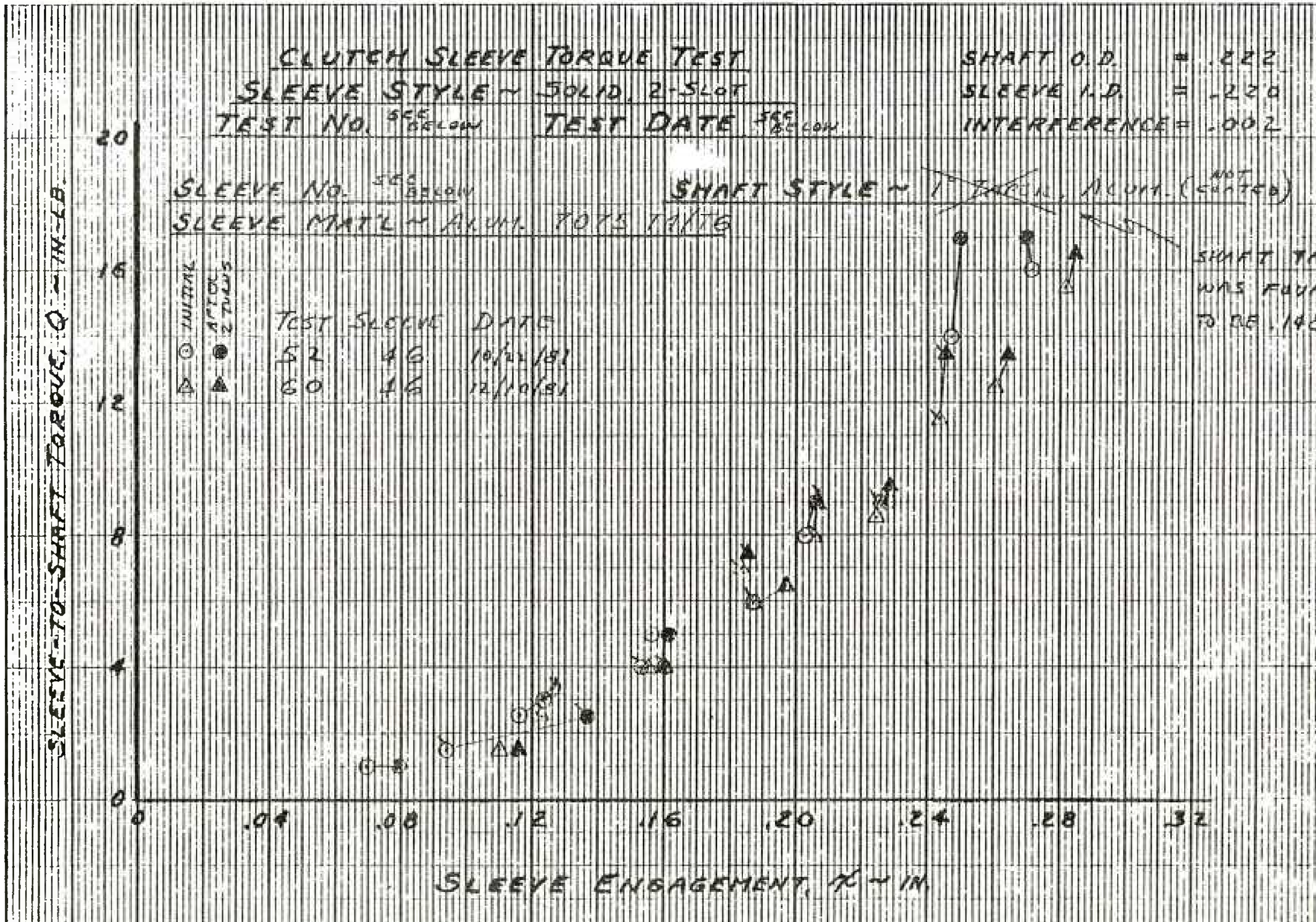


FIGURE 21

DATA FROM SHEET NO. S-3

The same tapered shaft designs, Figure 4(J), were then tried with aluminum sleeves at .009, .004 and .002 in. interference in Tests 56-59. Torque gradients were acceptable, but walk-off was again a problem at 1° taper.

It was then accidentally discovered that the shaft taper in Test 52 was not 1°, but 0.148°. Test 60 was a repeat of Test 52 using the same sleeve and shaft. Data from these two tests is shown in Figure 21, which indicates some repeatability.

As a consequence, shaft design (I) of Figure 4 was adopted and tested in aluminum with plain aluminum sleeves, Figure 2(K), with .001 in. interference. Results of several of these tests are presented in Figure 22, which represents the most repeatable collection of data achieved up to this point in the program. These data were acquired by measuring torque initially, before the sleeve began to slip on the shaft, and again before it began to slip, after having rotated two full turns on the shaft.

The next step was to install an aluminum setting shaft with an aluminum sleeve in a partly assembled M577 fuze so that the fuze could be set to its extreme time settings, that is, from 0 sec. time to 200 sec. time.

The desired slipping torque range is 9 to 13 in.-lb. To set this initially, the sleeve was pressed onto the shaft to an engagement distance that would give a torque within that range; the value of engagement to do this was read as $x = 0.22$ in., from Figure 22. A step wedge tool was made that was placed between the spacer on the knurled section of the shaft and the sleeve, so as to position the sleeve at the correct engagement. This procedure worked, such that correctly placing the sleeve on the shaft did achieve the desired torque.

NO. 318 AH. 20 DIVISIONS PER INCH BOTH WAYS. 180 BY 200 DIVISIONS. CODEX GRAPH PAPER

GR. 12-15-81 1-6-82
12-29-81 1-13-82
1-5-82

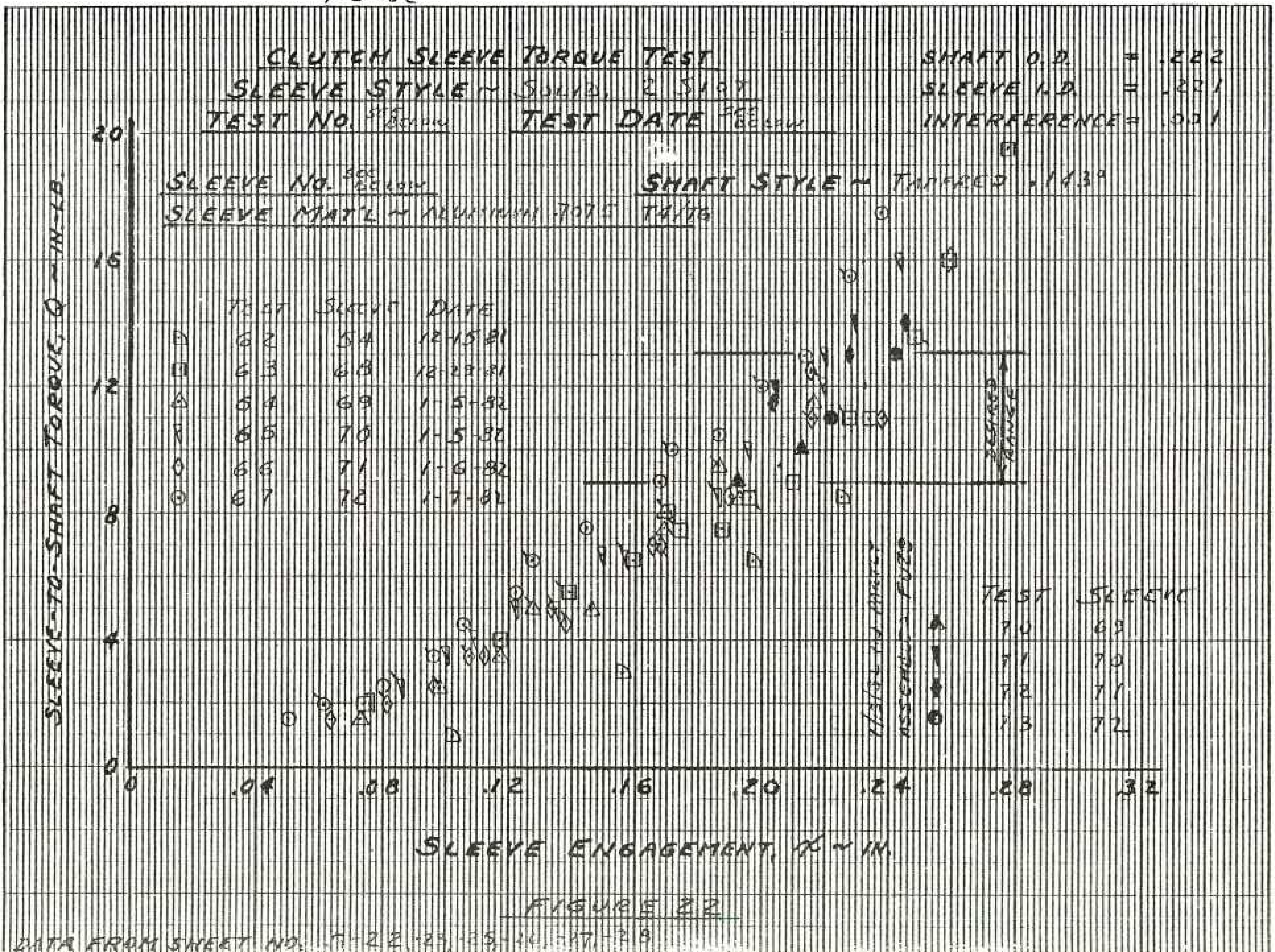


FIGURE 22

5-24

Torque was measured as slippage of the sleeve was impending at the zero second stop; then the shaft was turned twenty revolutions to the 200 sec. stop, where the torque was again measured. This sequence was repeated, the sleeve being permitted to slip about 1/10 of a turn at each extreme. After one full turn was made in 1/10 turn increments, the sleeve was continuously turned with the shaft against one of the stops, and the torque read at each whole number of turns. These tests were done both dry and lubricated with the lubricant presently being used on the production grip rings.

These data were plotted as Torque vs Number of Turns in Figures 23 and 24. The position of the sleeve on the shaft was also measured after each torque reading to detect movement; these data points are included in Figure 24.

These plots show that the sleeve torque increases as the number of turns increases, which is undesirable; also, the engagement decreases by .010 in. for every six or eight turns. This was the most promising design, in terms of repeatability of data when pushing a sleeve onto and off of a shaft; but, it was not a success with respect to maintaining a fixed range of slipping torque after a number of turns on the shaft.

The concept of the tapered (however slightly) shaft presents the problem of a component of force along the slope to accompany the radial force needed to produce resistance to rotation, as evidenced by the walk-off exhibited by certain combinations of sleeve configuration and material.

Engineering textbook tables of surface friction coefficients for aluminum on aluminum show higher values for sliding friction than for static friction. That appears to be true from the results here. Also a coefficient of friction increases as motion continues; a formation of a dark gray deposit of aluminum oxide takes place from the continuous fretting (friction oxidation) which changes the surface conditions, making results difficult to predict.

These were the final tests done for the '80 PIP Task 1.

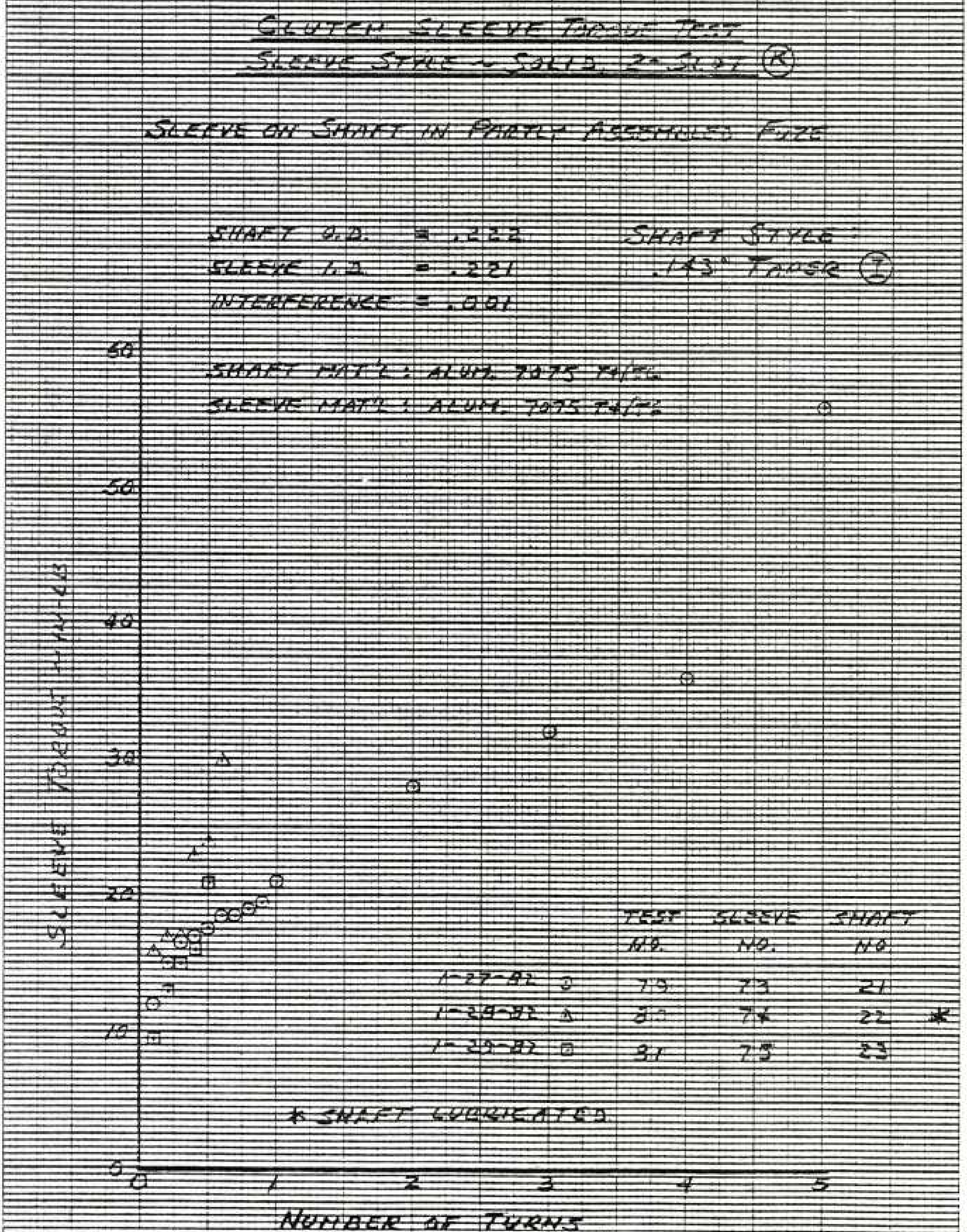

CLUTCH SLEEVE TORQUE TEST
SLEEVE STYLE ~ SOLID, 2-SLOT (R)
SLEEVE ON SHAFT IN PARTLY ASSEMBLED FUZE
SHAFT O.D. = .222
SLEEVE I.D. = .221
INTERFERENCE = .001
SHAFT STYLE: .143" TAPER (I)
SHAFT MAT'L: ALUM. 7075 T4/T6
SLEEVE MAT'L: ALUM. 7075 T4/T6
SLEEVE TORQUE ~ IN-LB
60
50
40
30
20
10
0
TEST NO.
SLEEVE NO.
SHAFT NO.
1-27-82 79 73 21
1-29-82 80 74 22 *
1-29-82 81 75 23
* SHAFT LUBRICATED
0
1
2
3
4
5
NUMBER OF TURNS

FIGURE 23

5-39

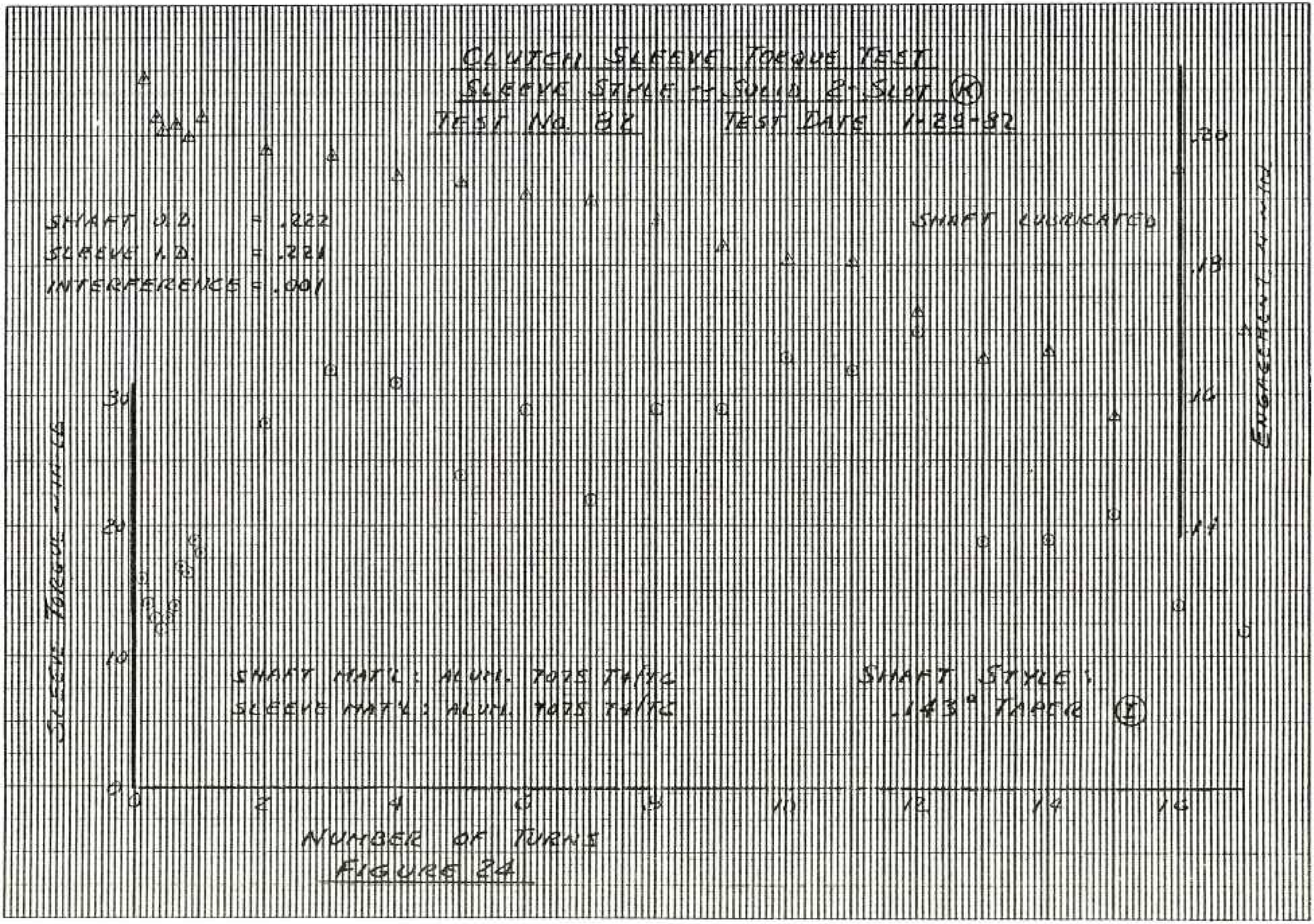


FIGURE 24

F. OTHER TYPES OF TESTS

To get some feel for the performance of the present production Grip Rings as compared to the sleeves tested, some testing was done with three different setting shafts - plain aluminum, stainless steel (present production design), and hard-coated aluminum. Torque was measured by turning the Grip Rings with the production Clutch Drive Sleeve and Setting Key.

The results are plotted in Figure 25, which shows the plain aluminum shaft to have the best gradient of Torque vs Engagement (no. of grip rings). Numerically, the value is about 0.6 in.-lb. per .010 in. of engagement, or about 2 in.-lb. per Grip Ring. The hard-coated shaft developed only about half as much torque.

G.R. 11-30-'81

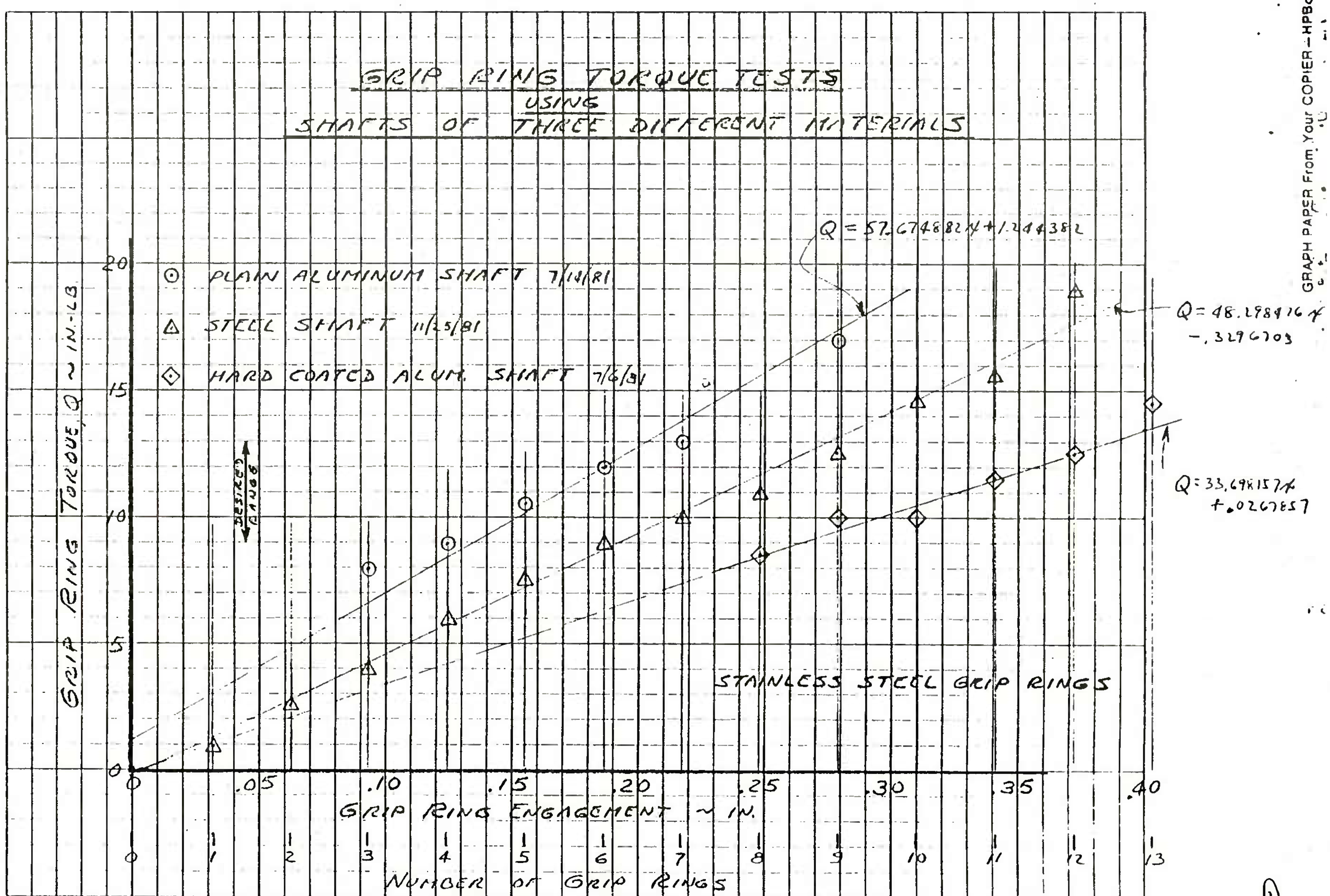


FIGURE 25

G-2

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